Appendix U – Environmental Comfort Assessment – Cannington Station prepared by ALUA

VICTORIA PARK TO CANNING

LEVEL CROSSING REMOVAL PROGRAM

PTA 200140

ENVIRONMENTAL COMFORT ASSESSMENT CANNINGTON STATION

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Definitions and Abbreviations

TABLE 0-1 – DEFINITIONS AND ABBREVIATIONS

ABBREVIATION	DESCRIPTION
CBD	CENTRAL BUSINESS DISTRICT
CSIRO	COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION
CSO	CUSTOMER SERVICES OFFICE
FDD	FINAL DETAIL DESIGN
GREEN STAR	GREEN STAR – RAILWAY STATIONS V1.1
NOA	NOTICE OF ADVICE
NRM	NATURAL RESOURCE MANAGEMENT
PTA	PUBLIC TRANSPORT AUTHORITY OF WESTERN AUSTRALIA
SWTC	SCOPE OF WORKS AND TECHNICAL CRITERIA

Executive Summary

This report presents the results of the environmental comfort study for Cannington Station's platform and concourse design. The assessments provide a high-level overview of the potential impacts the current station designs have on comfort due to environmental factors. The assessments do not consider safety impacts.

Initial assessments were completed in the early design stages to assess passenger comfort on the platform, which have now been updated to reflect the Final Detail Design (FDD). An additional assessment has also been completed on the FDD to assess the wind comfort at the station entrance. Following the first iteration of this report, additional investigations were completed on the Passenger Services Panel (ticketing machines) for the design team to explore potential supplementary rain protection opportunities.

Where applicable, the Green Star – Railway Stations v1.1 tool has been used as a benchmark to gauge whether the current designs provide suitable comfort strategies for commuters and staff. Green Star is an internationally recognised rating system that assesses best practice sustainability outcomes throughout the life cycle of the built environment. The Green Star – Railway Stations v1.1 tool is a customisation of Green Star – Design & As Built v1.2 tool and has been prepared for use on above ground and underground railway stations.

The information provided in the following report and previous assessments has been provided to inform the design as to the level of likelihood of rain, wind and sunlight impacting each area. How the risk is mitigated (e.g., nonslip surfaces or civil requirements to reduce pooling) is determined by the design team.

Scope Items

The Scope of Works and Technical Criteria (SWTC) and PTA Specification (8803-000-008 - Specification - Station Functional Planning and Urban Design) for Cannington Station includes several items relating to environmental comfort.

The following report is intended to provide comment on the scope items identified below.

TABLE 0-1 – SWTC SCOPE AND PTA SPECIFICATION ITEMS

#	Scope Item	Applicable Areas / Studies
22.1 Station Precinct, Station Buildings and Facilities General Requirements		
22.1-19	Platform Roofing: The NOP shall review provision of additional screening to mitigate potential for rain to encroach on (i.e., touch) the platform safe zones, pedestrian stairs, future escalators and/or lift zones at platform level during strong wind driven rain events.	Platform safe zones Pedestrian stairs Future escalators Lift zones
22.1-197 (i)	The NOP shall ensure the cover at each new station at a minimum: i. Prevents prevailing weather from impacting on Station Entry(s) and Station Foyer(s)	Station entry(s) Station foyer(s)
22.1-197 (ii)	The NOP shall ensure the cover at each new station at a minimum: ii. Ensures no wind driven rain or associated runoff affects or touches pedestrian stairwells, fare gates, ticketing	Pedestrian stairwells Fare gates Ticketing machines

#	Scope Item	Applicable Areas / Studies
	machines and dedicated platform safe zones, unless otherwise agreed in writing by the PTA.	Dedicated platform safe zones
22.4.5 Detailed Design		
22.4.5-3-18	Wind study demonstrating that the design of stations entry buildings and platforms enables comfortable and safe conditions. Note that wind safety is not covered within this NOA.	Station entry buildings Platforms
22.4.5-3-20	Environmental assessment including solar access and control, wind protection, rain protection, natural lighting; solar reflection; natural ventilation. Note that natural ventilation is not included within this NOA and will be covered by the mechanical engineering design team. * Note that natural lighting analysis is not considered applicable if the station is unstaffed and has no internal spaces intended to be occupied for extended periods of time requiring daylight. Refer to appendix for meeting minutes.	Solar access and control Wind Rain Protection Solar Reflection Natural lighting
22.11 Cannington Station Specific Requirements		
22.11-65	The NOP shall provide busway canopies as continuous roof cover between all bus stands and the Cannington Station entry building. The NOP shall ensure: i. All bus stands have sufficient shelter from sun and rain, including above front door of parked bus;	Busway Canopies
8803-000-008 - Specification - Station Functional Planning and Urban Design		
6.12	The platform canopy length shall: Extend for a minimum of 15 metres beyond the end of the vertical transportation on the platform	Lift zones platform level

Solar Access and Control

The sun's altitude and angle were analysed during the peak heat of the afternoon (2pm to 6pm) to determine whether there would be significant solar exposure on the platform. For the detailed assessment on solar access and control, refer to section 3.1.

TABLE 0-2 – SOLAR ACCESS AND CONTROL SCOPE ITEMS

Scope Item	Comments
22.4.5-3-20	*Environmental assessment including solar access and control, wind protection, rain protection, natural lighting; solar reflection; natural ventilation.* Note that natural ventilation is not included within this report and will be covered by the mechanical engineering design team.

Scope Item	Comments
	A solar access and control environmental assessment has been completed in section 3.1.2 below. The assessment determined the following: • At 2pm, for areas of the platform under the narrow canopy, some solar exposure will occur on the edge of the platform particularly during spring and autumn. Areas with the wider canopy, and enclosed by the metal sheeting canopy shell, will be mostly protected from the summer sun with limited exposure to the autumn and winter sun. The 20% shaded target for Green Star is likely to be met at 2pm from spring to autumn. • At 6pm, due to the low altitude of the sun there will be full solar exposure for areas not enclosed by the canopy shell. Areas enclosed by the perforated metal sheeting of the canopy shell will be somewhat protected, dependant on the perforation size. As an indicative assessment, with a small perforation size, the 20% shaded target for Green Star may be met.
22.9-77	*The NOP shall provide busway canopies as continuous roof cover between all bus stands and the Cannington Station entry building. The NOP shall ensure:* *i. All bus stands have sufficient shelter from sun and rain, including above front door of parked bus;* At 2pm, busway areas under a shelter canopy are expected to be provide some areas of shade from the summer solstice, autumn equinox and spring equinox sun angles. At 6pm, the bus shelter areas will likely see solar exposure penetrate under the bus shelter canopy. Some limited shade may be provided to passengers by the bus shelter's perforated weather screen.

Solar Reflection

The sun path for Perth was used to determine any areas prone to risk of glare to staff, patrons and train drivers. The assessments only analyse potential reflectivity glare from new infrastructure in the development. The assessments do not consider safety or human comfort. For the detailed assessment on solar reflection, refer to section 0.

TABLE 0-3 – SOLAR REFLECTION SCOPE ITEMS

Scope Item	Comments
22.4.5-3-20	*Environmental assessment including solar access and control, wind protection, rain protection, natural lighting; solar reflection; natural ventilation.* Note that natural ventilation is not included within this report and will be covered by the mechanical engineering design team. A solar reflection environmental assessment has been completed in section 3.2.2 below which identified the following: In the early hours of the morning: • The sun will be at a low altitude and angled from the East. Therefore, the sun could potentially reflect off any shiny surfaces under the platform canopy to the East and impact train drivers and/or passengers on the Down Main Platform.

Scope Item	Comments
	• Depending on the properties of the canopy shell perforated screening, it may be possible for morning glare to penetrate from the East and potentially reflect of any shiny surfaces under the canopy shell towards the East. This could potentially impact train drivers on both train lines and/or passengers on the Up Main platform. In the late evening: • The sun will be at a low altitude and angled from the West. Therefore, the sun could potentially reflect off any shiny surfaces under the platform canopy to the West and impact train drivers and/or passengers on the Up Main Platform. • Depending on the properties of the canopy shell perforated screening, it may be possible for evening glare to penetrate from the West and potentially reflect of any shiny surfaces under the canopy shell towards the West. This could potentially impact train drivers on both train lines and/or passengers on the Down Main platform. • Refer to previous NOA and desktop studies for potential design solutions to be implemented by the design team.

Rain Protection

The prevailing wind speeds and directions when it is raining were assessed to provide advice on probable rainfall angles and their impact on waiting passengers. For the detailed assessment on rain protection, refer to section 3.3.

Following a discussion with the Public Transport Authority of Western Australia (PTA) on Thursday the 8th of December, it was clarified that some minimal wind driven rain will be allowable on station areas, should the design be able to demonstrate that water will not pool in these areas and patron safety is considered (i.e., nonslip surfaces). How the risk is mitigated (e.g., nonslip surfaces or civil requirements to reduce pooling) is determined by the design team. Refer to appendix for meeting minutes.

TABLE 0-4 – RAIN PROTECTION SCOPE ITEMS

Scope Item	Comments
22.1-19	*Platform Roofing: The NOP shall review provision of additional screening to mitigate potential for rain to encroach on (i.e., touch) the platform safe zones, pedestrian stairs, future escalators and/or lift zones at platform level during strong wind driven rain events.* When rain is falling, Westerly and Northerly winds are the prevailing wind directions. The Western and Northern rain angle environmental assessments have been completed in section 3.3.3 and are summarised below. When reading the assessments, note that historic data indicates, in total, it rains for 7% of the year. **Typical Platform:** The Western rain could enter the full depth of both the Up and Down Main Typical Platform depending on the rainfall angle. The most common occurring Western rainfall angle (which impacts the Typical Platform Zones) will occur for less than approximately 3.6% of the time annually based on historical data. The Northern rain could enter the full depth of both the Up and Down Main Typical Platform depending on the rainfall angle. The most common occurring Northern rainfall angle (which impacts approximately half the Typical Platform Zones) will occur for less than approximately 5.3% of the time annually based on historical data.

Scope Item	Comments
	Platform Safe Zones: It is expected that the canopy roof and perforated metal sheeting in the canopy shell will provide some protection to the Platform Safe Zones from Western and Northern rain but will not completely prevent rain from entering (where the screen is perforated). Note that it rains for only 7% of the year, based on past weather data from Jandakot Weather Station. **Lift zones:** It is expected that the canopy roof and perforated metal sheeting in the canopy shell will provide some protection to the Lift Zones from Western and Northern rain but will not completely prevent rain from entering (where the screen is perforated). Note that it rains for only 7% of the year, based on past weather data from Jandakot Weather Station. **Staff and Public Pedestrian Stairs Zones:** It is expected that the overhanging roof and perforated metal sheeting in the canopy shell will provide some protection to the Public Pedestrian Zones from Western and Northern rain but will not completely prevent rain from entering (where the screening is perforated). Due to the exposed design and lack of protection, the Northern and Western rain could enter the full depth of the Staff Pedestrian Stairs Zones depending on the rainfall angle. **Escalator** It is expected that the overhanging roof and platform canopy will provide some protection to the Escalator Zones from Western and Northern rain but will not completely prevent rain from entering. The area will be impacted by the Western rain for 1.7% of the year and Northern rain for 1% of the year. **Station Entry and Foyer:** The Western rain could enter the full depth of both the North and South Station Entry and Foyer depending on the rainfall angle. The most common occurring Western rainfall angle (which impacts the Station Entry and Foyer) will occur for less than approximately 4.9% of the time annually based on historical data. The Northern rain could enter the full depth of the North and South Station Entry and Foyer depending on the rainfall angle. The most common occurring Northern rainfall angle (which impacts the Station Entry and Foyer Zones) will occur for less than approximately 5.7% of the time annually based on historical data.
22.1-197 (i)	*The NOP shall ensure the cover at each new station at a minimum:* *i. Prevents prevailing weather from impacting on Station Entry(s) and Station Foyer(s)* Refer to 22.1-19 comments for Station Entry and Foyer.
22.1-197 (ii)	*The NOP shall ensure the cover at each new station at a minimum:* *ii. Ensures no wind driven rain or associated runoff affects or touches pedestrian stairwells, fare gates, ticketing machines and dedicated platform safe zones, unless otherwise agreed in writing by the PTA.* Refer to 22.1-19 comments for Platform Safe Zones, Pedestrian Stairwells, Station Entry and Foyer. **Ticketing machines**

Scope Item	Comments
	It is unlikely rain from the West will impact the ticketing machines on the Northern corner of the station entry due to the rail corridor above. Additional canopy cover has been provided to increase protection from the most common Northern rainfall angles (occurring 82.3% of the time it is raining or less than 5.7% of the time annually). Should the rain fall at a greater rainfall due to greater wind speeds, the ticketing machines may still be impacted for a small percentage of the time it is raining.
22.4.5-3-20	*Environmental assessment including solar access and control, wind protection, rain protection, natural lighting; solar reflection; natural ventilation.* Note that natural ventilation is not included within this NOA and will be covered by the mechanical engineering design team. The Western and Northern rain angle analyses have been completed to assess the rain protection as identified above. Refer to 22.1-19 comments.
PTA Specification 6.12	*The platform canopy length shall:* *Extend for a minimum of 15 metres beyond the end of the vertical transportation on the platform.* Canopy length exceeds minimum of 15 metre length requirement.
22.9-77	*The NOP shall provide busway canopies as continuous roof cover between all bus stands and the Cannington Station entry building. The NOP shall ensure:* *i. All bus stands have sufficient shelter from sun and rain, including above front door of parked bus;* Western rain may land under the rail corridor and impact areas not provided with a weather screen in the bus shelter depending on the rainfall angle. Where weather screens are provided, there will be a level of protection for passengers waiting under the bus canopies. Similarly, the Northern rain could enter the full depth of the bus shelters, where no weather screen is installed, depending on the rainfall angle. However, the most commonly occurring Northern rainfall angles (cumulative rate of 82.3%) will impact only a small portion of area under the canopies, the remainder will most likely be protected.

Wind Protection

Prevailing winds and average wind speeds were assessed to determine whether the prevailing winds would cause discomfort for passengers at the station, as per the Lawson comfort criteria[1]. The criteria is based on the probability of exceeding certain mean wind speeds. Per the Lawson comfort criteria, wind conditions are uncomfortable when the probability of the mean wind speed exceeding the given number is greater than 5%. For the detailed assessment on wind protection, refer to section 3.4.

[1] Lawson, T. (1978). The Wind Content of the Built Environment. Journal of Wind Engineering and Industrial Aerodynamics, Volume 3, Issues 2-3, 93-105

TABLE 0-5 – WIND PROTECTION SCOPE ITEMS

Scope Item	Comments
22.1-197 (i)	*The NOP shall ensure the cover at each new station at a minimum:* *i) Prevents prevailing weather from impacting on Station Entry(s) and Station Foyer(s)* The prevailing wind direction and average speeds have been assessed in section 3.4.2 below. **Station Entry and Foyer:** In line with the Lawson comfort criteria, the average wind speeds from the prevailing wind directions are considered comfortable for passengers sitting or standing for short periods of time.
22.4-5-3-18	*Wind study demonstrating that the design of stations entry buildings and platforms enables comfortable and safe conditions.* Note that wind safety is not covered within this report. **Station Entry and Foyer:** As identified above, in line with the Lawson comfort criteria, the average wind speeds from the prevailing wind directions are considered comfortable for passengers sitting or standing for short periods of time. **Platforms:** In line with the Lawson comfort criteria, the average wind speeds from the prevailing wind directions are considered uncomfortable for passengers sitting or standing for short periods of time. However, some protection may be provided via infrastructure on the platform (i.e., staff office, comms room and perforated screening). It is noted that the perforated screening will not provide full protection. These objects may provide some protection from the prevailing winds for more than 10% of the platform, meeting the Green Star Railway v1.1. best practice requirements. The canopy shell may also provide some protection from the prevailing winds to the section of the platform it envelops, however the screen is permeable and may not provide full protection.
22.4.5-3-20	*Environmental assessment including solar access and control, wind protection, rain protection, natural lighting; solar reflection; natural ventilation.* Note that natural ventilation is not included within this NOA and will be covered by the mechanical engineering design team. Refer to 22.4-5-3-18 above.
PTA Specification 6.12	*The platform canopy length shall:* *Extend for a minimum of 15 metres beyond the end of the vertical transportation on the platform.* Due to the glass adjacent to the lifts, there is some protection from the prevailing winds at each lift entry. An extended canopy is not expected to provide additional protection from the wind without a vertical element to the canopy, as the passengers would be exposed to wind underneath the canopy.

Natural Lighting

Daylight access to regularly staffed areas has been analysed in line with the Green Star Daylight and Views Hand Calculation Guide to determine natural lighting amenity for occupants.

As a benchmark, Green Star requires 50% of the total primary space (areas where a person is expected to work or remain for an extended period of time such as ticket counters, offices and retail areas) to achieve good daylight amenity. Refer to Appendix C for details on the calculation requirements for daylight amenity.

For the detailed assessment on natural lighting, refer to section 3.5.

TABLE 0-6 - SCOPE ITEMS ADDRESSED

Scope Item	Comments
22.4.5-3-20	*Environmental assessment including solar access and control, wind protection, rain protection, natural lighting; solar reflection; natural ventilation.* Note that natural ventilation is not included within this NOA and will be covered by the mechanical engineering design team. A daylight amenity assessment has been completed in section 3.5.2 below. The assessment determined that the Customer Services Office, the staff office and more than 90% of the kiosk will have good access to natural light, meeting best practice requirements as per Green Star Railway Stations v1.1. For improved daylight access, each occupied primary space should ensure a VLT of greater than 40% to all glazing.

1. Introduction

To provide guidance for the development of station designs for the Victoria Park-Canning Level Crossing Removal Program, an environmental comfort study has been completed to assess solar access and control, solar reflection, rain protection and wind protection for commuter comfort.

Initial assessments were completed in the early design stages to assess passenger comfort on the platform, which have now been updated to reflect FDD design. Following the first iteration of this report, additional investigations were completed on the Passenger Services Panel (ticketing machines) for the design team to explore potential supplementary rain protection opportunities.

The assessments provide a high-level overview of the potential impacts that the station designs have on comfort due to environmental factors. They do not consider safety or wind gust impacts.

Where applicable, the Green Star – Railway Stations v1.1 tool has been used as a benchmark to gauge whether the current designs provide suitable comfort strategies for commuters and staff. Green Star is an internationally recognised rating system that assesses best practice sustainability outcomes throughout the life cycle of the built environment. The Green Star – Railway Stations v1.1 tool is a customisation of Green Star – Design & As Built v1.2 tool and has been prepared for use on above ground and underground railway stations.

The information provided in the following report and previous assessments has been provided to inform the design as to the level of likelihood of rain, wind and sunlight impacting each area. How the risk is mitigated (e.g., nonslip surfaces or civil requirements to reduce pooling) is determined by the design team.

Table 1-1 below provides the list of drawings and models used to perform the above analysis.

TABLE 1-1 – REFERENCES

Reference	Drawing Name	Date
BIM360 3D Model	LXR-P2-Z3-CN-SN-AR-M3D-00001.rvt	Accessed week of 06/03/2023
BIM 360 2D Drawings	Station Wide Axonometric (04-A-73-AR-0050) Station Wide Locality Plan (04-A-73-AR-0055) Station Wide Site Plan (04-A-73-AR-0056) General Arrangement GA Plans (04-A-73-AR-0057) General Arrangement GA Elevations (04-A-73-AR-0060) GA Elevations – Building Facades – Sheets 1-5 (04-A-73-AR-0089 to 04-A-73-AR-0093) General Arrangement Concourse Plan – Zone C (04-A-73-AR-0065)	Accessed week of 06/03/2023 Accessed week of 22/05/2023 for Passenger Services Panel updates only

2. Station Details

2.1 Location and Weather

Historic weather data from Jandakot weather station was obtained from the Bureau of Meteorology for the analysis. Jandakot is the closest weather station to Cannington Station, located within 10km to the Northwest of the station. Refer to Appendix for additional details on the weather data.

2.1.1 Climate Change

While historic weather data has been used to complete the assessments, it is important to note that climate change may have an impact on the weather at Cannington Station.

The CSIRO and the Bureau of Meteorology's regional climate projections for Australia provide detailed climate projections for regions around Australia. These projections are arranged by natural resource management (NRM) regions. The NRM regions are grouped into 'clusters' and 'sub clusters', which are broader climate and bio-physical regions around Australia for which tailored climate projections have been modelled. Cannington Station is located in the Southern and South-Western Flatlands West sub cluster.

Climate change projections for the Cannington Station location indicate that average annual rainfall is expected to decline, however the intensity of rainfall events is projected to increase. Time spent in drought is projected to increase over the course of the century.

2.2 Station Design

The following memo details the environmental comfort results for Cannington Station. Under the proposed Victoria Park-Canning Level Crossing Removal Program works, a new station will be developed.

The proposed design includes:

- New station building
- New elevated platforms and railway track
- New concourse
- New utilities
- New amenities
- New retail space
- New staff crib and amenities
- New bus interchange
- New community plaza area

Figure 2-1 to Figure 2-5 show the proposed station design.

Figure 2-1 below shows an architectural illustration of the station building. The station includes the new elevated rail and platforms to remove the Cannington level crossing.

FIGURE 2-1 – PROPOSED WORKS (STATION ILLUSTRATION)

Figure 2-2 below shows the proposed design of the new ground floor concourse and the station entry.

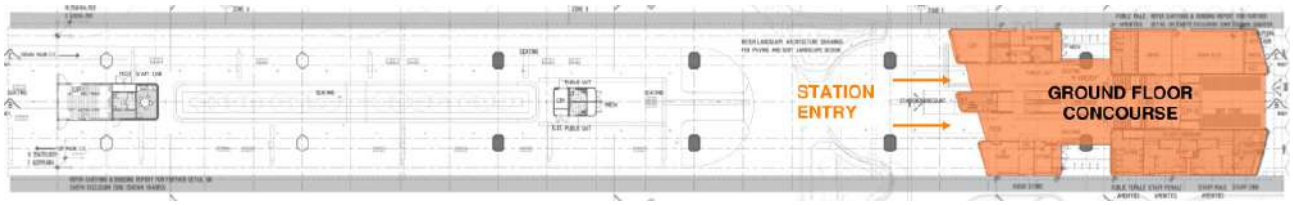


FIGURE 2-2 PROPOSED WORKS (GROUND FLOOR CONCOURSE)

The design has adopted an island platform arrangement. Figure 2-3 below indicates the new Up Main platform and Down Main platform.

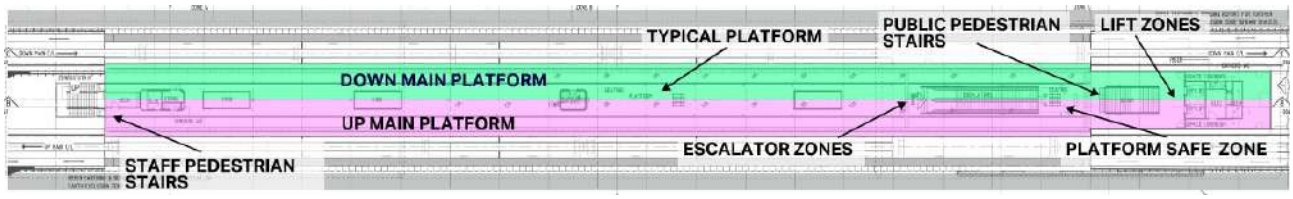


FIGURE 2-3 PROPOSED WORKS (PLATFORMS)

As illustrated in Figure 2-4 and Figure 2-5 below, the perforated weather screen with a height of approximately 1.8m (from platform level), runs along the boundary of the rail corridors. Additionally, a perforated metal sheeting canopy shell is used to protect certain areas of the platforms.

FIGURE 2-4 PROPOSED PERFORATED WEATHER SCREEN, PERFORATED METAL SHEETING AND TRANSPARENT SCREEN (WEST ELEVATION)

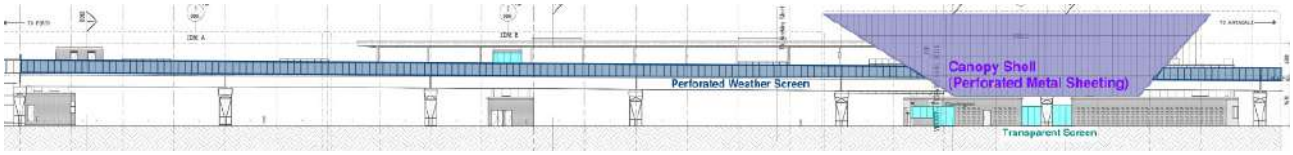
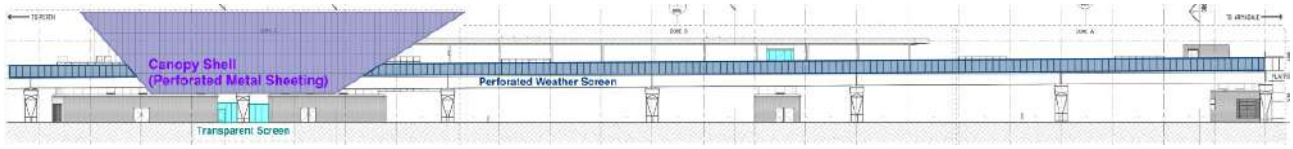
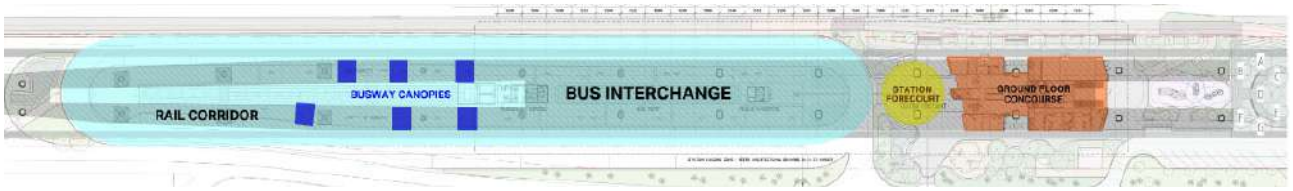


FIGURE 2-5 PROPOSED PERFORATED WEATHER SCREEN, PERFORATED METAL SHEETING AND TRANSPARENT SCREEN (EAST ELEVATION)



The project also includes a new bus interchange within the precinct, highlighted in blue in Figure 2-6, to the South of the station buildings.

FIGURE 2-6 PROPOSED CANNINGTON PRECINCT WITH BUS INTERCHANGE



2.2.1 Key Changes Since Reference Design

Key changes to the design since the Reference Design desktop study that impact the environmental comfort assessment include:

- Increase in glass screening adjacent to escalators
- Updates to canopy shell (change from louvres to perforated screening)
- Increase in canopy cover overlap with canopy shell

2.3 Scope Items

The Scope of Works and Technical Criteria (SWTC) and PTA Specification (8803-000-008 - Specification - Station Functional Planning and Urban Design) for Cannington Station includes several items relating to environmental comfort. These are identified in Table 2-1 below.

The following report is intended to provide comment on the scope items identified below.

TABLE 2-1 - SWTC SCOPE AND PTA SPECIFICATION ITEMS

#	Scope Item	Applicable Areas / Studies
22.1 Station Precinct, Station Buildings and Facilities General Requirements		
22.1-19	Platform Roofing: The NOP shall review provision of additional screening to mitigate potential for rain to encroach on (i.e., touch) the platform safe zones, pedestrian stairs, future escalators and/or lift zones at platform level during strong wind driven rain events.	Platform safe zones Pedestrian stairs Escalators Lift zones

#	Scope Item	Applicable Areas / Studies
		Bus Shelter
22.1-197 (i)	The NOP shall ensure the cover at each new station at a minimum: i. Prevents prevailing weather from impacting on Station Entry(s) and Station Foyer(s)	Station entry(s) Station foyer(s)
22.1-197 (ii)	The NOP shall ensure the cover at each new station at a minimum: ii. Ensures no wind driven rain or associated runoff affects or touches pedestrian stairwells, fare gates, ticketing machines and dedicated platform safe zones, unless otherwise agreed in writing by the PTA.	Pedestrian stairwells Fare gates Ticketing machines Dedicated platform safe zones
22.4.5 Detailed Design		
22.4.5-3-18	Wind study demonstrating that the design of stations entry buildings and platforms enables comfortable and safe conditions. Note that wind safety is not covered within this NOA.	Station entry buildings Platforms
22.4.5-3-20	Environmental assessment including solar access and control, wind protection, rain protection, natural lighting; solar reflection; natural ventilation. Note that natural ventilation is not included within this NOA and will be covered by the mechanical engineering design team. * Note that natural lighting analysis is not considered applicable if the station is unstaffed and has no internal spaces intended to be occupied for extended periods of time requiring daylight. Refer to appendix for meeting minutes.	Solar access and control Wind Rain protection Solar reflection Natural lighting
22.11 Cannington Station Specific Requirements		
22.11-65	The NOP shall provide busway canopies as continuous roof cover between all bus stands and the Cannington Station entry building. The NOP shall ensure: i. All bus stands have sufficient shelter from sun and rain, including above front door of parked bus;	Busway Canopies
8803-000-008 - Specification - Station Functional Planning and Urban Design		
6.12	The platform canopy length shall: Extend for a minimum of 15 metres beyond the end of the vertical transportation on the platform	Lift zones platform level

2.4 Assessment Areas

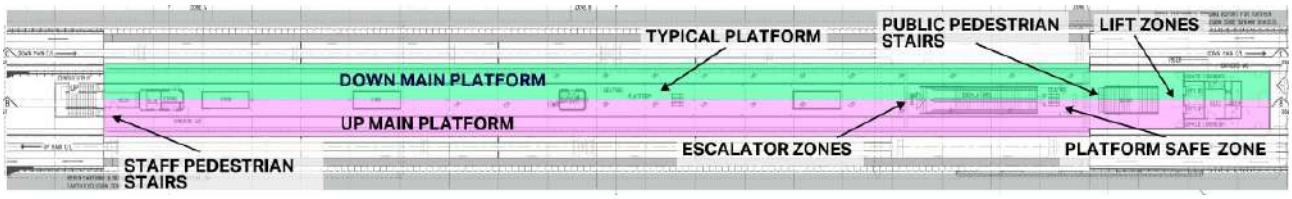
2.4.1 Platform Assessment Areas

In line with the SWTC environmental comfort scope items, appliable areas and studies were identified for Cannington Station Platforms. Consequently, the environmental assessment is conducted on various locations of both platforms as shown in Figure 2-7. These locations include typical platform area, pedestrian stairs areas, platform safe zones, escalator zones and lift zones.

It is assumed that the architectural canopy shell and weather screening with perforated metal sheeting provides some protection from solar exposure, wind and rain. The screening will not fully restrict either of these weather elements from entering and the performance of each screen may differ.

Note that environmental comfort studies assess general conditions and cannot evaluate the screening's specific effects.

FIGURE 2-7 PLATFORM ASSESSMENT AREAS



2.4.2 Concourse Assessment Areas

The environmental assessment has also been completed for the station entry and foyer as shown in Figure 2-2 to assess the prevailing weather factors that may affect the area in line with the SWTC environmental comfort scope items. Given the fare gates and ticketing machines will be in the foyer near the station entrance, the assessment results will be consistent with those of the station entrance.

2.4.3 Regularly Staffed Spaces Assessment Areas

A daylight access assessment has also been completed for areas where a person is expected to work or remain for an extended period of time. The Kiosk, Customer Services Office (CSO), Staff Office and Staff Cribs, as shown below in **Error! Reference source not found.** have been identified as qualifying areas that require good daylight amenity in line with the SWTC environmental comfort scope items.

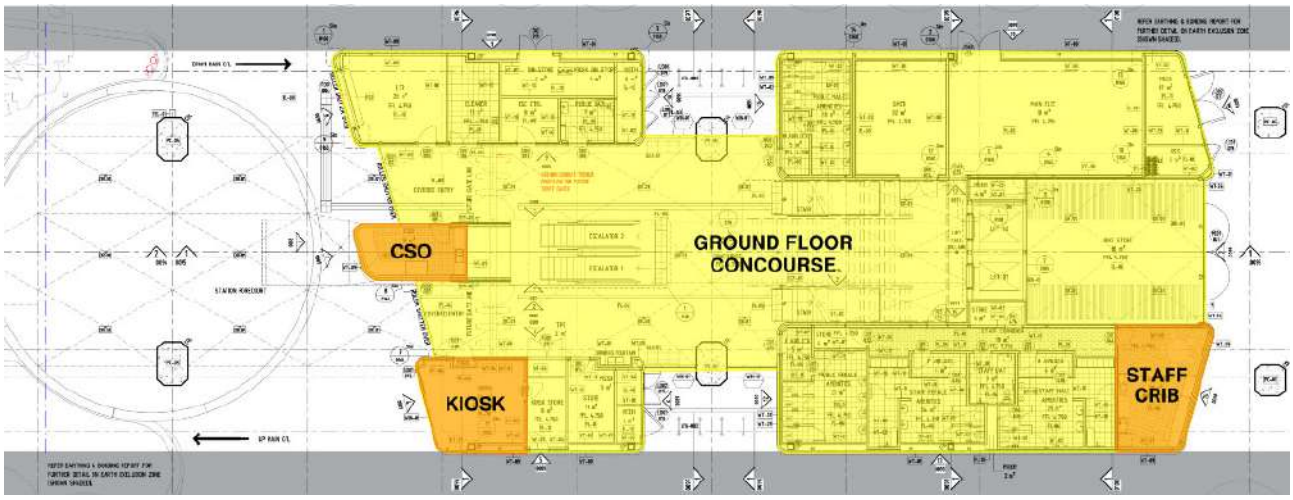


FIGURE 2-8 NATURAL DAYLIGHT ASSESSMENT AREAS – GROUND FLOOR

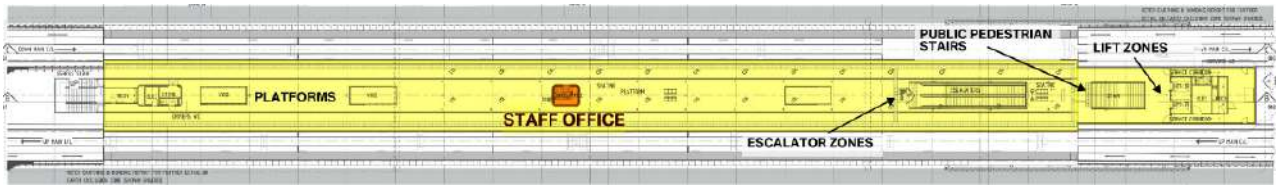


FIGURE 2-9 NATURAL DAYLIGHT ASSESSMENT AREAS – PLATFORM LEVEL

3. Environmental Comfort Assessment

3.1 Solar Access and Control

The following assessment analyses how shaded the nominated plane (platform level) is from direct sunlight at autumn and spring equinoxes and the summer solstice. This assessment is performed to check if the shading provided protects passengers from extensive sun exposure to assist achievement of an acceptable level of comfort on the platform.

As a benchmark for this analysis, Green Star – Railway Stations v1.1 requires at least 20% of the area of each platform to be shaded for afternoon peak periods (2pm to 6pm) during the warmest half of the year (spring equinox to autumn equinox).

3.1.1 Scope Items

The table below identifies which scope items the solar access and control assessment relates to and summarises the assessment findings.

TABLE 3-1 - SCOPE ITEMS ADDRESSED

Scope Item	Comments
22.4.5-3-20	*Environmental assessment including solar access and control, wind protection, rain protection, natural lighting; solar reflection; natural ventilation.* Note that natural ventilation is not included within this report and will be covered by the mechanical engineering design team. A solar access and control environmental assessment has been completed in section 3.1.2 below. The assessment determined the following: • At 2pm, for areas of the platform under the narrow canopy, some solar exposure will occur on the edge of the platform particularly during spring and autumn. Areas with the wider canopy, and enclosed by the metal sheeting canopy shell, will be mostly protected from the summer sun with limited exposure to the autumn and winter sun. The 20% shaded target for Green Star is likely to be met at 2pm from spring to autumn. • At 6pm, due to the low altitude of the sun there will be full solar exposure for areas not enclosed by the canopy shell. Areas enclosed by the perforated metal sheeting of the canopy shell will be somewhat protected, dependant on the perforation size. As an indicative assessment, with a small perforation size, the 20% shaded target for Green Star may be met.
22.9-77	*The NOP shall provide busway canopies as continuous roof cover between all bus stands and the Cannington Station entry building. The NOP shall ensure:* *i. All bus stands have sufficient shelter from sun and rain, including above front door of parked bus;* At 2pm, busway areas under a shelter canopy are expected to be provide some areas of shade from the summer solstice, autumn equinox and spring equinox sun angles. At 6pm, the bus shelter areas will likely see solar exposure penetrate under the bus shelter canopy. Some limited shade may be provided to passengers by the bus shelter's perforated weather screen.

3.1.2 Assessment Results

3.1.2.1 Platforms

Figure 3-1 and Figure 3-2 below indicate that the island platform, where it is protected only by the platform canopy, will be partially shaded from the 2pm sun. However, will likely see 6pm solar exposure penetrate under the canopy, impacting the full depth of the platform. This is indicated in the figures below as red (summer solstice), orange (autumn equinox) and yellow (spring equinox).

There are two sets of large skylights set into the platform canopy. These are likely to allow considerable solar exposure to the platform areas below from the 2pm sun. However, at 6pm, direct solar exposure through the skylights to the platform is likely to be negligible.

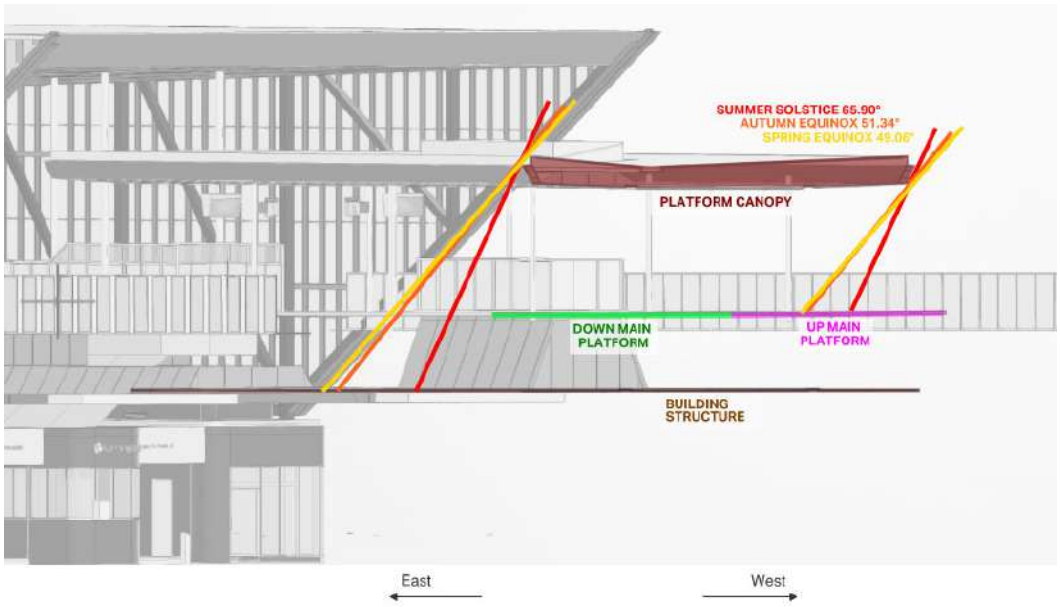


FIGURE 3-1 SUN ALTITUDE 2PM (TYPICAL PLATFORM AREA)

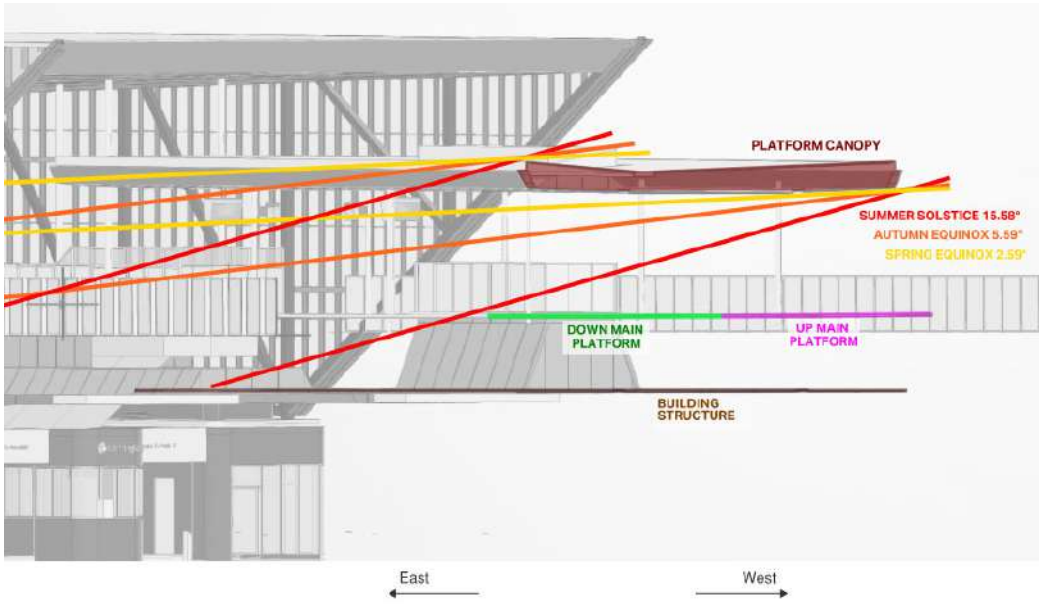


FIGURE 3-2 SUN ALTITUDE 6PM (TYPICAL PLATFORM AREA)

Platform areas, such as the Safe Zone, that are enclosed by the perforated metal sheeting of the canopy shell are expected to be shaded between 2pm and 6pm. Though, it is likely that some indirect solar exposure may penetrate through the perforations to reach the platforms. This interaction of sunlight and the canopy shell construction is demonstrated in Figure 3-3 and Figure 3-4.

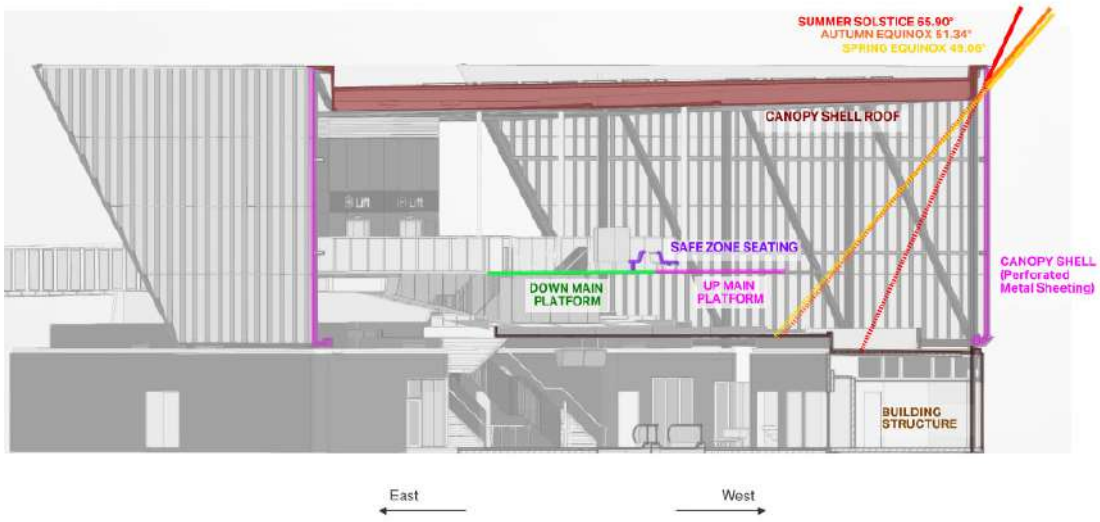


FIGURE 3-3 SUN ALTITUDE 2PM (SAFE ZONE PLATFORM AREA)

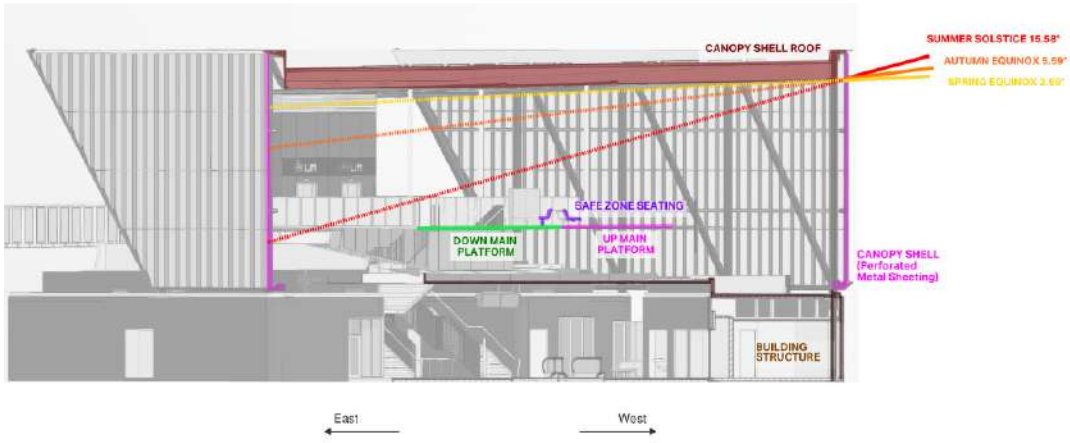


FIGURE 3-4 SUN ALTITUDE 6PM (SAFE ZONE PLATFORM AREA)

Figure 3-5 and Figure 3-6 show the azimuth angle (the compass direction from which the sunlight is coming) on the island platform. These diagrams should be read in conjunction with the diagrams above.

The figures demonstrate that when the azimuth angle is taken into consideration, at 2pm, the platforms are relatively exposed to the autumn, spring and summer sun. Due to the azimuth angles of the autumn and spring suns, there is likely to be more shade to areas covered with the platform canopy during these seasons than when compared to the summer season. However, the southwestern end of the platform is partially protected from summer azimuth due to the perforated metal sheeting of the canopy shell (depicted by the pink lines). Note that these diagrams should be read in conjunction with those above.

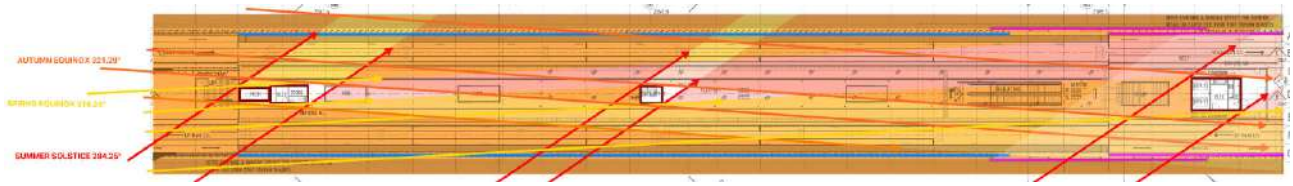


FIGURE 3-5 SUN AZIMUTH ANGLE 2PM (PLAN)

At 6pm, platform areas not enclosed by the canopy shell are likely to be exposed to sunlight during summer, autumn and spring. However, some solar protection may be afforded to areas under the canopy shell by its perforated metal sheeting. Note that these diagrams should be read in conjunction with those above.

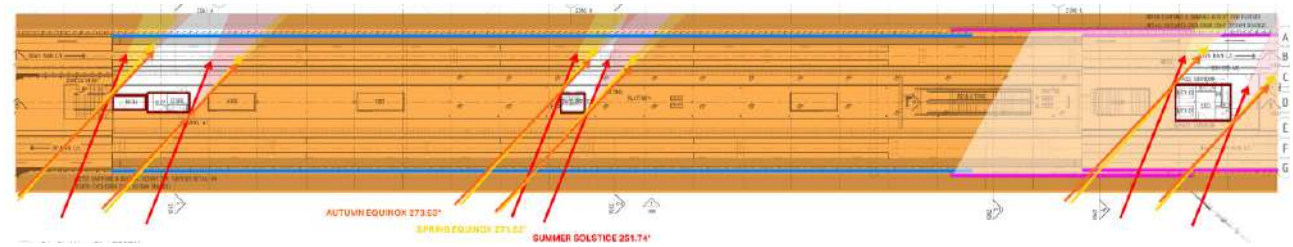


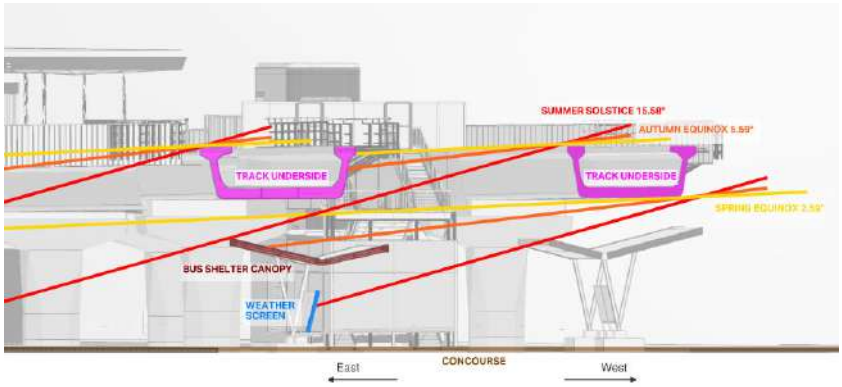
FIGURE 3-6 SUN AZIMUTH ANGLE 6PM (PLAN)

3.1.2.2 Busway Canopies

Busway areas under a shelter canopy are likely to provide some shade at 2pm from spring to autumn. This is demonstrated in Figure 3-7 with the lines representing the 2pm sun altitude angles of summer solstice (red), autumn equinox (orange) and spring equinox (yellow).

FIGURE 3-7 SUN ALTITUDE 2PM ON DOWN MAIN (TOP) AND UP MAIN (BOTTOM) BUS SHELTERS

Figure 3-8 below indicates that, at 6pm, the bus shelter areas will likely see solar exposure penetrate under the bus shelter canopy from spring to autumn. The bus shelters under the Up Main rail corridor may be less shaded than the Down Main bus shelters at this time of day. Some limited shade may be provided to passengers by the bus shelter's perforated weather screen.



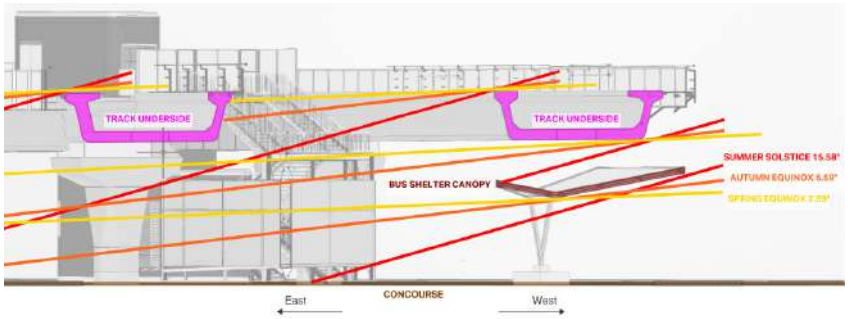


FIGURE 3-8 SUN ALTITUDE 6PM ON DOWN MAIN (TOP) AND UP MAIN (BOTTOM) BUS SHELTERS

3.2 Solar Reflection

The analysis involves overlaying sun paths specific to Perth with the station design and observing how the sun angles may interact with the station building. The assessments only analyse potential reflectivity glare from the new station building. The assessments do not consider safety or human comfort.

3.2.1 Scope Items

The table below identifies which scope items the solar reflection assessment relates to and summarises the assessment findings.

TABLE 3-2 - SCOPE ITEMS ADDRESSED

Scope Item	Comments
22.4.5-3-20	*Environmental assessment including solar access and control, wind protection, rain protection, natural lighting; solar reflection; natural ventilation.* Note that natural ventilation is not included within this report and will be covered by the mechanical engineering design team. A solar reflection environmental assessment has been completed in section 3.2.2 below which identified the following: In the early hours of the morning: • The sun will be at a low altitude and angled from the East. Therefore, the sun could potentially reflect off any shiny surfaces under the platform canopy to the East and impact train drivers and/or passengers on the Down Main Platform. • Depending on the properties of the canopy shell perforated screening, it may be possible for morning glare to penetrate from the East and potentially reflect of any shiny surfaces under the canopy shell towards the East. This could potentially impact train drivers on both train lines and/or passengers on the Up Main platform. In the late evening: • The sun will be at a low altitude and angled from the West. Therefore, the sun could potentially reflect off any shiny surfaces under the platform canopy to the West and impact train drivers and/or passengers on the Up Main Platform. • Depending on the properties of the canopy shell perforated screening, it may be possible for evening glare to penetrate from the West and potentially reflect of any shiny surfaces under the canopy shell towards the West. This could potentially impact train drivers on both train lines and/or passengers on the Down Main platform.

Scope Item	Comments
	Refer to previous NOA and desktop studies for potential design solutions to be implemented by the design team.

3.2.2 Assessment Results

Figure 3-9 below shows the sun path overlaid over a portion of the proposed platform. The sun path shows the path the sun takes as it travels from East to West across the year, indicated in yellow in the figure. The directions where the sun is shining from is indicated by the angles on the circumference on the circle and the altitude of the sun is indicated by the concentric circles. The lines bounding the annual variation zone (yellow), the green line and blue line, denote the path of the sun when travelling across the June (winter) solstice and December (summer) solstice, respectively. Refer to Appendix A for additional details on the sun path diagram.

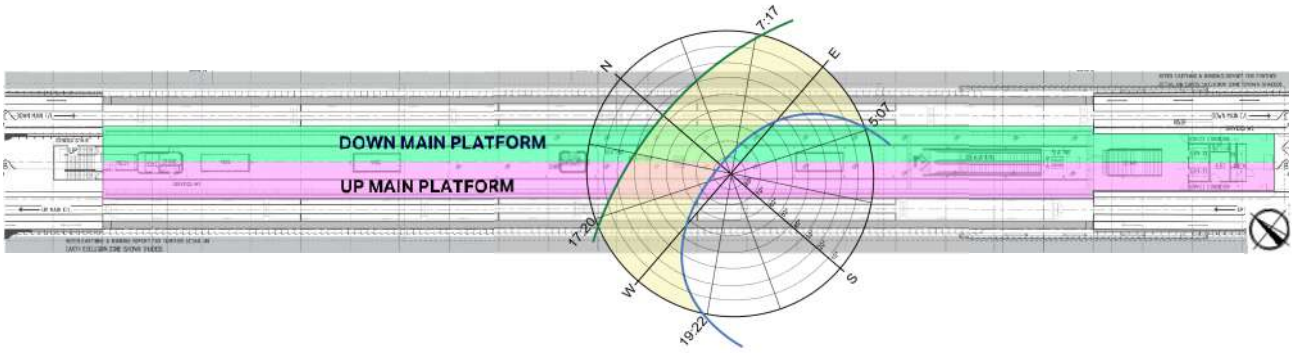


FIGURE 3-9 SUN PATH DIAGRAM

3.3 Rain Protection

The aim of this analysis is to provide advice on probable rainfall and its impact on waiting passengers on the platforms.

As a benchmark, Green Star Railway Stations v1.1 requires that 80% of the platform should be protected from rain for stations with high peak occupancy. Stations with high peak occupancy refers to stations where morning and afternoon commuting passengers regularly fill the platform.

Following a discussion with the Public Transport Authority of Western Australia (PTA) on Thursday the 8th of December, it was clarified that some minimal wind driven rain will be allowable on station areas, should the design be able to demonstrate that water will not pool in these areas and patron safety is considered (i.e., nonslip surfaces). The information in the following report is provided to inform the design as to the level of likelihood of rain, wind and sunlight impacting each area. How the risk is mitigated (e.g., nonslip surfaces or civil requirements to reduce pooling) will be determined by the design team. Refer to appendix for meeting minutes.

Historical rain and wind data obtained from the Bureau of Meteorology was used to determine the prevailing wind direction and rain angle. For Cannington Station, weather data from the Jandakot weather station was used. Refer to Appendix A for details on the calculation methods proposed for this analysis.

3.3.1 Rainfall and Wind

3.3.1.1 Rainfall

In Jandakot, it rains for 7% of the year based on historic weather data. Below are the months and times of the day when this rainfall is most likely to occur. The tables indicate:

- The majority (54%) of rainfall occurs in winter
- The time of day at which rainfall occurs is evenly distributed throughout the day

TABLE 3-3 - FREQUENCY OF RAINFALL BASED ON SEASON

Period	Months	Occurrence
Summer	Dec - Feb	7%
Autumn	Mar - May	20%
Winter	Jun - Aug	54%
Spring	Sep - Nov	19%

TABLE 3-4 - FREQUENCY OF RAINFALL BASED ON THE TIME OF THE DAY

Period	Time	Occurrence
Night	0:00 - 06:00	27%
Morning	06:00 - 12:00	24%
Afternoon	12:00 - 18:00	23%
Evening	18:00 - 24:00	26%

3.3.1.2 Wind

To determine the possible angles at which the rain is likely to fall, the wind speed and wind direction are required. The analysis determined that when rain is falling, there are two prevailing wind directions:

- West (240° to 300°) accounting for 36.8% of the annual hours when precipitation occurs
- North (10° to 20°) accounting for 9.7% of the annual hours when precipitation occurs

The wind speeds in these directions were then analysed to determine the likely rainfall angle. Refer to Appendix A for further details.

The prevailing wind directions when it is raining are shown in Figure 3-10 and Figure 3-11 below.

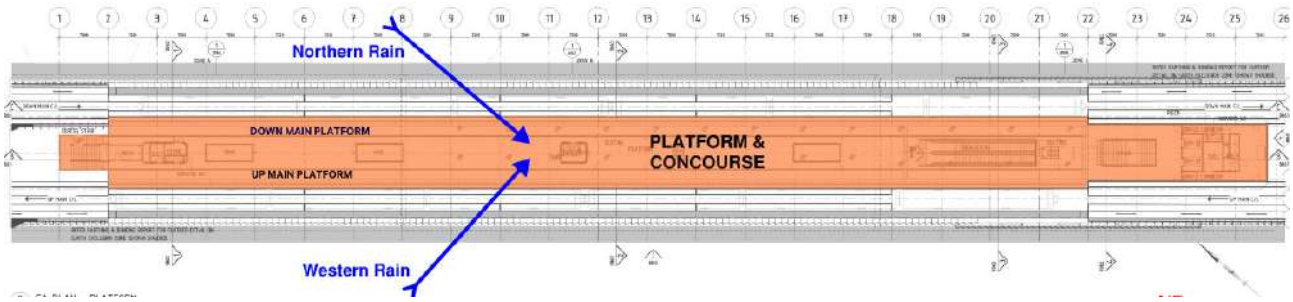


FIGURE 3-10 PLAN

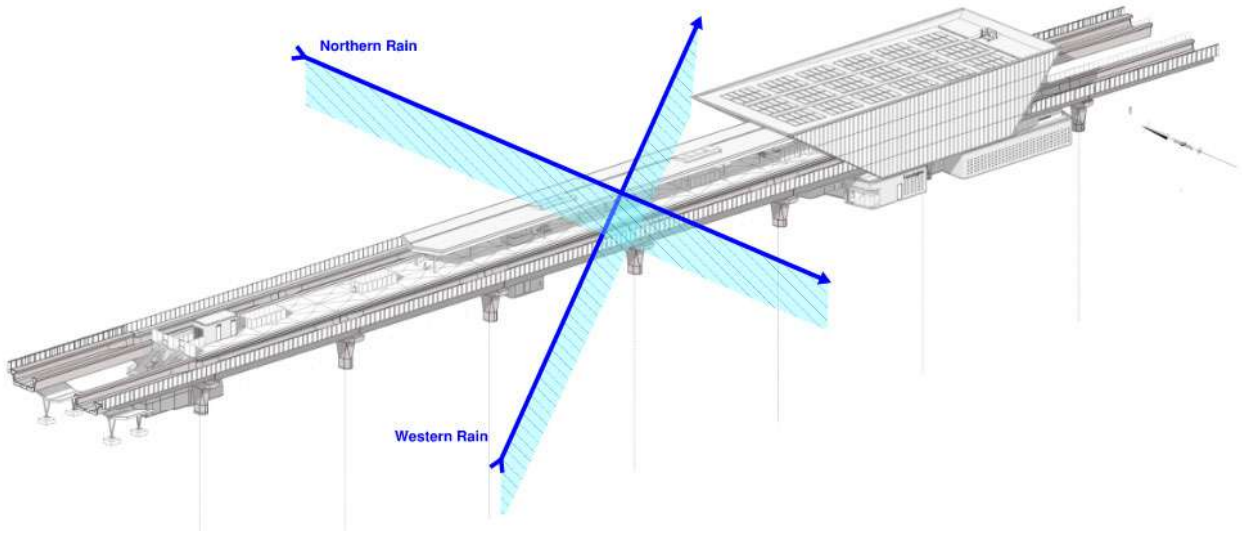


FIGURE 3-11 AXONOMETRIC (VISUAL REPRESENTATION)

3.3.1.3 Western Rain

When rain is occurring, rain from the Western direction is likely to fall from the following angles at 1 metre and 9.5 metres high (these two heights have been selected as a representation of ground-level wind speeds and platform height windspeeds):

TABLE 3-5 WESTERN RAIN FREQUENCY AT 1M AND 9.5M (WHEN RAINING)

1 metre (ground level)	9.5 metres above ground level (approximate platform height)
▪ 0° to 11° - less than 1% ▪ 11° to 17° (purple) – 2.2% ▪ 17° to 28° (red) – 17.4% ▪ 28° to 50° (yellow) – 37.6% ▪ 50° to 78° (green) – 32.9% ▪ 78° to 90° (blue) – 9.7%	▪ 0° to 11° (grey) - 10% ▪ 11° to 17° (purple) – 19.8% ▪ 17° to 28° (red) – 26.5% ▪ 28° to 50° (yellow) – 24.6% ▪ 50° to 78° (green) – 14.9% ▪ 78° to 90° (blue) – 4.2%

Considering past data shows it rains for 7% of the year and Table 3-6 shows the frequency when raining, the above percentages could translate to the following percentages across the entire year (e.g., inclusive of rain and non-rain periods). Note that these numbers are provided as a guide only as the 7% of the year is inclusive of rain in all directions whereas the above is inclusive of the Western rain only. The approach and percentages below are therefore a conservative representation.

TABLE 3-6 WESTERN RAIN FREQUENCY AT 1M AND 9.5M (ACROSS YEAR)

1 metre (ground level)	9.5 metres above ground level (approximate platform height)
▪ 0° to 11° - less than 1% ▪ 11° to 17° (purple) – less than 1% ▪ 17° to 28° (red) – 1.2% ▪ 28° to 50° (yellow) – 2.6% ▪ 50° to 78° (green) – 2.3% ▪ 78° to 90° (blue) – less than 1%	▪ 0° to 11° (grey) - less than 1% ▪ 11° to 17° (purple) – 1.4% ▪ 17° to 28° (red) – 1.9% ▪ 28° to 50° (yellow) – 1.7% ▪ 50° to 78° (green) – 1.0% ▪ 78° to 90° (blue) – less than 1%

3.3.1.4 Northern Rain

When rain is occurring, rain from the northern direction is likely to fall from the following angles at 1 metre and 9.5 metres high:

TABLE 3-7 – NORTHERN RAIN FREQUENCY AT 1M AND 9.5M (WHEN RAINING)

1 metre (ground level)	9.5 metres above ground level (approximate platform height)
▪ 0° to 11° - less than 1% ▪ 11° to 17° (purple) – 1.1% ▪ 17° to 28° (red) – 3.1% ▪ 28° to 50° (yellow) – 13.4% ▪ 50° to 78° (green) – 60.4% ▪ 78° to 90° (blue) – 21.9%	▪ 0° to 11° - less than 2.2% ▪ 11° to 17° (purple) – 4.0% ▪ 17° to 28° (red) – 10.3% ▪ 28° to 50° (yellow) – 33.7% ▪ 50° to 78° (green) – 41.0% ▪ 78° to 90° (blue) – 8.7%

Considering past data shows it rains for 7% of the year and Table 3-7 shows the frequency when raining, the above percentages could translate to the following percentages across the year (e.g., inclusive of rain and non-rain periods). Note that these numbers are provided as a guide only as the 7% of the year is inclusive of rain in all directions whereas the above is inclusive of the Northern rain only. The approach and percentages below are therefore a conservative representation.

TABLE 3-8 – NORTHERN RAIN FREQUENCY AT 1M AND 9.5M (ACROSS YEAR)

1 metre (ground level)	9.5 metres above ground level (approximate platform height)
▪ 0° to 11° - less than 1% ▪ 11° to 17° (purple) – less than 1% ▪ 17° to 28° (red) – less than 1% ▪ 28° to 50° (yellow) – less than 1% ▪ 50° to 78° (green) – 4.2% ▪ 78° to 90° (blue) – 1.5%	▪ 0° to 11° (grey) - less than 1% ▪ 11° to 17° (purple) – less than 1% ▪ 17° to 28° (red) – less than 1% ▪ 28° to 50° (yellow) – 2.4% ▪ 50° to 78° (green) – 2.9% ▪ 78° to 90° (blue) – less than 1%

3.3.2 Scope Items

The table below identifies which scope items the rainfall protection assessment relates to and summarises the assessment findings.

TABLE 3-9 - SCOPE ITEMS ADDRESSED

Scope Item	Comments
22.1-19	*Platform Roofing: The NOP shall review provision of additional screening to mitigate potential for rain to encroach on (i.e., touch) the platform safe zones, pedestrian stairs, future escalators and/or lift zones at platform level during strong wind driven rain events.*

Scope Item	Comments
	When rain is falling, Westerly and Northerly winds are the prevailing wind directions. The Western and Northern rain angle environmental assessments have been completed in section 3.3.3 and are summarised below. When reading the assessments, note that historic data indicates, in total, it rains for 7% of the year. **Typical Platform:** The Western rain could enter the full depth of both the Up and Down Main Typical Platform depending on the rainfall angle. The most common occurring Western rainfall angle (which impacts the Typical Platform Zones) will occur for less than approximately 3.6% of the time annually based on historical data. The Northern rain could enter the full depth of both the Up and Down Main Typical Platform depending on the rainfall angle. The most common occurring Northern rainfall angle (which impacts approximately half the Typical Platform Zones) will occur for less than approximately 5.3% of the time annually based on historical data. **Platform Safe Zones:** It is expected that the canopy roof and perforated metal sheeting in the canopy shell will provide some protection to the Platform Safe Zones from Western and Northern rain but will not completely prevent rain from entering (where the screen is perforated). Note that it rains for only 7% of the year, based on past weather data from Jandakot Weather Station. **Lift zones:** It is expected that the canopy roof and perforated metal sheeting in the canopy shell will provide some protection to the Lift Zones from Western and Northern rain but will not completely prevent rain from entering (where the screen is perforated). Note that it rains for only 7% of the year, based on past weather data from Jandakot Weather Station. **Staff and Public Pedestrian Stairs Zones:** It is expected that the overhanging roof and perforated metal sheeting in the canopy shell will provide some protection to the Public Pedestrian Zones from Western and Northern rain but will not completely prevent rain from entering (where the screening is perforated). Due to the exposed design and lack of protection, the Northern and Western rain could enter the full depth of the Staff Pedestrian Stairs Zones depending on the rainfall angle. **Escalator** It is expected that the overhanging roof and platform canopy will provide some protection to the Escalator Zones from Western and Northern rain but will not completely prevent rain from entering. The area will be impacted by the Western rain for 1.7% of the year and Northern rain for 1% of the year. **Station Entry and Foyer:** The Western rain could enter the full depth of both the North and South Station Entry and Foyer depending on the rainfall angle. The most common occurring Western rainfall angle (which impacts the Station Entry and Foyer) will occur for less than approximately 4.9% of the time annually based on historical data.

Scope Item	Comments
	The Northern rain could enter the full depth of the North and South Station Entry and Foyer depending on the rainfall angle. The most common occurring Northern rainfall angle (which impacts the Station Entry and Foyer Zones) will occur for less than approximately 5.7% of the time annually based on historical data.
22.1-197 (i)	*The NOP shall ensure the cover at each new station at a minimum:* *i. Prevents prevailing weather from impacting on Station Entry(s) and Station Foyer(s)* Refer to 22.1-19 comments for Station Entry and Foyer.
22.1-197 (ii)	*The NOP shall ensure the cover at each new station at a minimum:* *ii. Ensures no wind driven rain or associated runoff affects or touches pedestrian stairwells, fare gates, ticketing machines and dedicated platform safe zones, unless otherwise agreed in writing by the PTA.* Refer to 22.1-19 comments for Platform Safe Zones, Pedestrian Stairwells, Station Entry and Foyer. **Ticketing machines** It is unlikely rain from the West will impact the ticketing machines on the Northern corner of the station entry due to the rail corridor above. Additional canopy cover has been provided to increase protection from the most common Northern rainfall angles (occurring 82.3% of the time it is raining or less than 5.7% of the time annually). Should the rain fall at a greater rainfall due to greater wind speeds, the ticketing machines may still be impacted for a small percentage of the time it is raining.
22.4.5-3-20	*Environmental assessment including solar access and control, wind protection, rain protection, natural lighting; solar reflection; natural ventilation.* Note that natural ventilation is not included within this NOA and will be covered by the mechanical engineering design team. The Western and Northern rain angle analyses have been completed to assess the rain protection as identified above. Refer to 22.1-19 comments.
PTA Specification 6.12	*The platform canopy length shall:* *Extend for a minimum of 15 metres beyond the end of the vertical transportation on the platform.* Canopy length exceeds minimum of 15 metre length requirement.
22.9-77	*The NOP shall provide busway canopies as continuous roof cover between all bus stands and the Cannington Station entry building. The NOP shall ensure:* *i. All bus stands have sufficient shelter from sun and rain, including above front door of parked bus;* Western rain may land under the rail corridor and impact areas not provided with a weather screen in the bus shelter depending on the rainfall angle. Where weather screens are provided, there will be a level of protection for passengers waiting under the bus canopies.

Scope Item	Comments
	Similarly, the Northern rain could enter the full depth of the bus shelters, where no weather screen is installed, depending on the rainfall angle. However, the most commonly occurring Northern rainfall angles (cumulative rate of 82.3%) will impact only a small portion of area under the canopies, the remainder will most likely be protected.

3.3.3 Assessment Results

As mentioned in Section 2.4, in line with the SWTC environmental comfort scope, assessment areas of both platforms and the station building (listed below) were identified for rain protection:

- Typical Platform (Section 3.3.3.1)
- Platform safe zones (Section 3.3.3.2)
- Lift zones (Section 3.3.3.3)
- Staff and Public Pedestrian stairs area (Section 3.3.3.40)
- Escalator (Section3.3.3.5)
- Station Entry and Foyer (Section 3.3.3.6)
- Ticketing Machines (Section 3.3.3.7)
- Bus Shelter (Section3.3.3.8)

3.3.3.1 Typical Platform

Western Rain

Figure 3-12 below shows how Western rain may interact with the proposed platform canopy above the concourse. Based on the diagram, the rain from the West is expected to penetrate the full depth of both the Up and Down Main Typical Platforms depending on the rainfall angle.

Rain from the West direction at 9.5m high will most likely fall at the yellow and red rain angles as identified by the percentage above in section 3.3.1. The areas encompassed by the yellow and red rain angles typically occur for 51.1% of the time it is raining from the West (less than approximately 3.6% of the time annually).

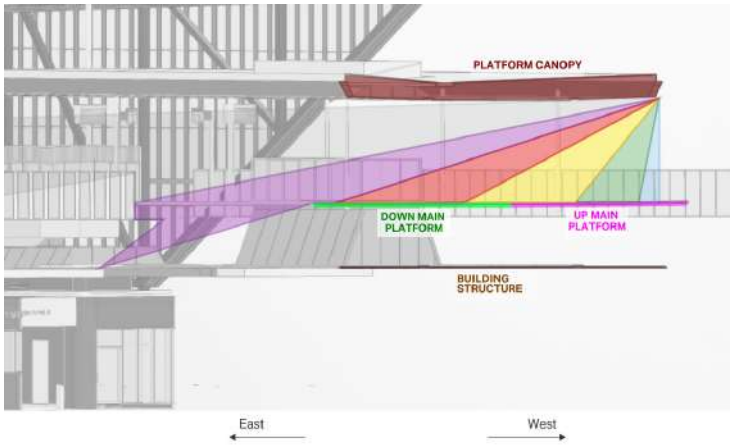


FIGURE 3-12 TYPICAL PLATFORM WESTERN RAIN ANGLES

Northern Rain

Figure 3-13 shows that with the proposed canopy and platform design, rain from the North could penetrate the full depth of both the Up and Down Main Typical Platform depending on the rainfall angle.

Rain from the North direction at 9.5m high will most likely fall at the green and yellow rain angles as identified by the percentages above in section 3.3.1. The areas encompassed by the green and yellow rain angles typically occur 74.7% of the time it is raining from the North (less than approximately 5.3% of the time annually).

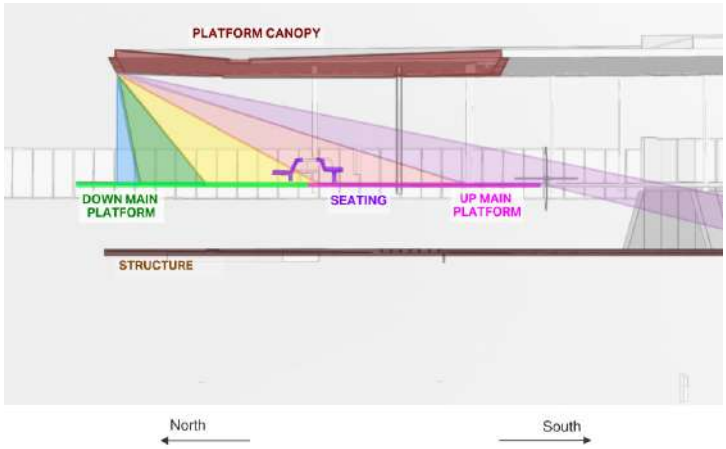


FIGURE 3-13 TYPICAL PLATFORM NORTHERN RAIN ANGLES

3.3.3.2 Platform Safe Zone

Western Rain

Figure 3-14 demonstrates how Western rain may interact with the proposed canopy shell roof and perforated metal sheeting in the portion of the Up and Down Main Platform Safe Zones above the concourse.

The canopy roof with a 5m extension over the platform edge and the perforated metal sheeting are expected to provide some protection against rain from the West, but not complete protection (where the screening is perforated). However, this will only occur for a small percentage of the year (noting it rains for only 7% of the year, based on past weather data from Jandakot Weather Station).

Note that environmental comfort studies assess general conditions and cannot evaluate the perforated screening's specific effects.

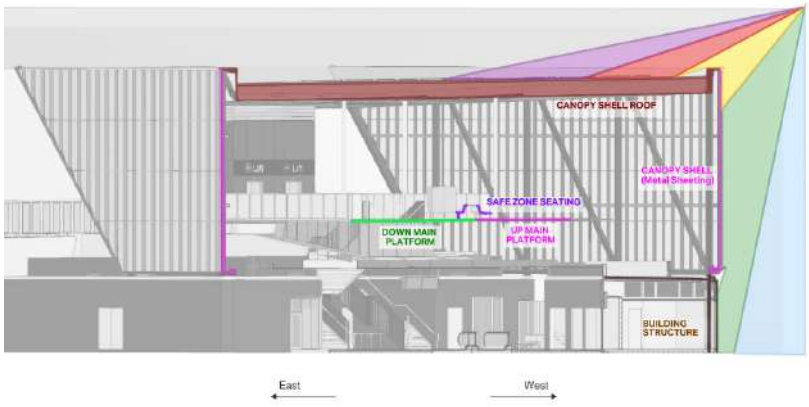


FIGURE 3-14 PLATFORM SAFE ZONE WESTERN RAIN ANGLES

Northern Rain

FIGURE 3-15 shows how Northern rain may interact with the proposed canopy shell roof and perforated metal sheeting around the portion of both the Up and Down Main Platform Safe Zone above the concourse.

The canopy roof with a 5m extension over the platform edge and the perforated metal sheeting are expected to provide some protection against rain from the North, but not complete protection (where the screening is

perforated). However, this will only occur for a small percentage of the year (noting it rains for only 7% of the year, based on past weather data from Jandakot Weather Station).

Note that environmental comfort studies assess general conditions and cannot evaluate the perforated screening's specific effects.

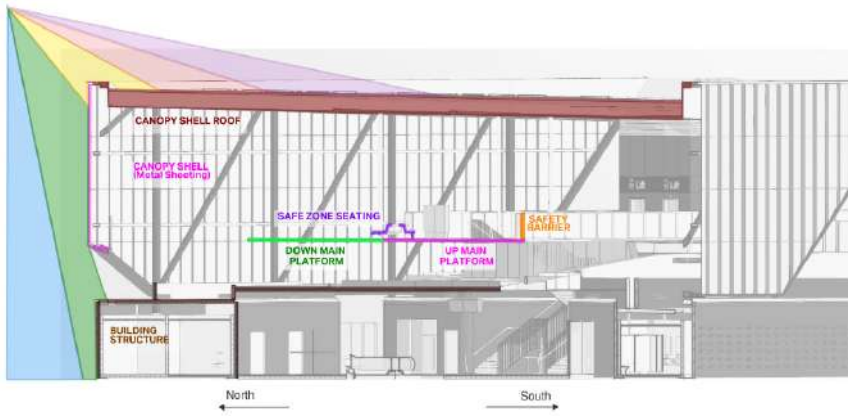


FIGURE 3-15 PLATFORM SAFE ZONE NORTHERN RAIN ANGLES

3.3.3.3 Lift Zones

Figure 3-16 demonstrates how the prevailing rain directions will likely interface with each lift entry zone.

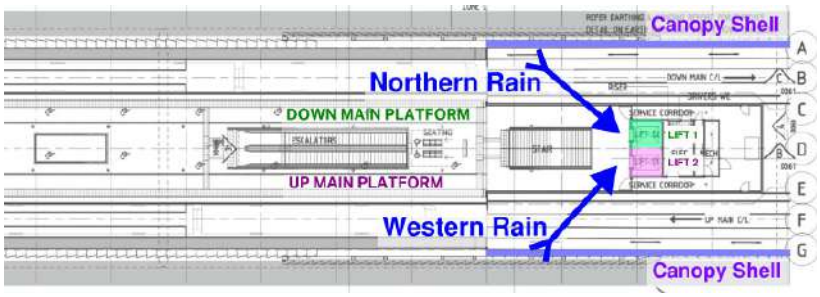


FIGURE 3-16 PLAN VIEW OF RAIN DIRECTION

Western Rain

Figure 3-17 below analyses the impact of Western rain on the Lift 1 and 2 entry area with the cover of the canopy shell roof and perforated metal sheeting.

From this assessment, the canopy roof with a 5m extension over the platform edge and the perforated metal sheeting are expected to provide some protection against rain from the West, but not complete protection to the Lift 1 and 2 entry area (where the screening is perforated). However, this will only occur for a small percentage of the year (noting it rains for only 7% of the year, based on past weather data from Jandakot Weather Station).

Note that environmental comfort studies assess general conditions and cannot evaluate the perforated screening's specific effects.

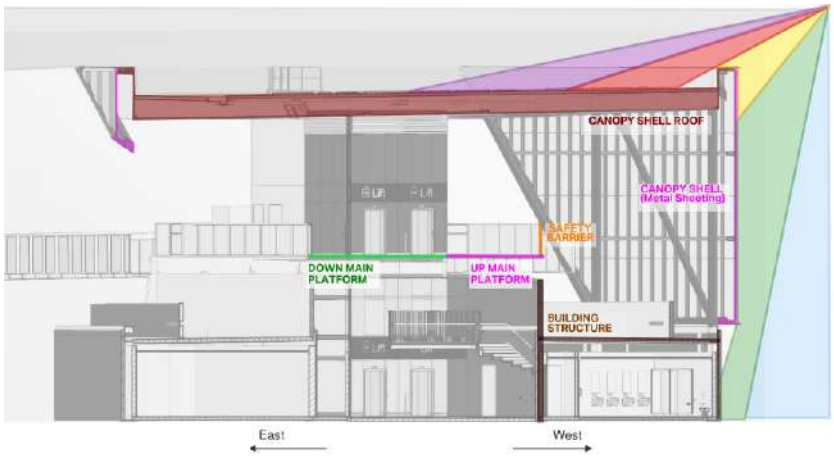


FIGURE 3-17 PLATFORM LIFT ZONES WESTERN RAIN ANGLES

Northern Rain

Figure 3-18 below analyses how Northern rain may impact the Lift 1 and 2 entry area with the cover of the canopy shell roof and perforated metal sheeting.

From this assessment, the canopy roof with a 5m extension over the platform edge and the perforated metal sheeting are expected to provide some protection against rain from the North, but not complete protection to the Lift 1 and 2 entry area (where the screening is perforated). However, this will only occur for a small percentage of the year that it rains (noting it rains for only 7% of the year, based on past weather data from Jandakot Weather Station).

Note that environmental comfort studies assess general conditions and cannot evaluate the perforated screening's specific effects.

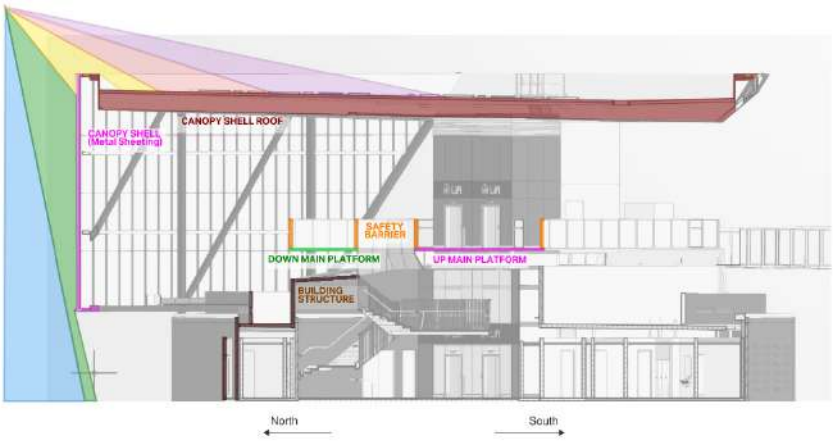


FIGURE 3-18 PLATFORM LIFT ZONES NORTHERN RAIN ANGLES

3.3.3.4 Platform Egress and Public Pedestrian Stairs

Western Rain

Figure 3-19 below analyses how Western rain may impact the Public Pedestrian Stair with the cover of the overhanging canopy shell roof and perforated metal sheeting.

From this assessment, the overhanging roof with a 5m extension over the platform edge and the perforated metal sheeting are expected to provide some protection against rain from the West, but not complete protection to the Public Pedestrian Stair (where the screening is perforated). However, this will only occur for a small percentage of the year that it rains (noting it rains for only 7% of the year, based on past weather data from Jandakot Weather Station).

Note that environmental comfort studies assess general conditions and cannot evaluate the perforated screening's specific effects.

FIGURE 3-19 PLATFORM PEDESTRIAN STAIRS WESTERN RAIN ANGLES

Figure 3-20 demonstrates that the Western rain may penetrate the full depth of the Platform Egress Stairs depending on the rainfall angle.

Due to the exposed design and lack of protection, the Western rain will have an impact on the Platform Egress Stairs, however, this will only occur for the small percentage of the year that it rains (noting it rains for only 7% of the year, based on past weather data from Jandakot Weather Station).

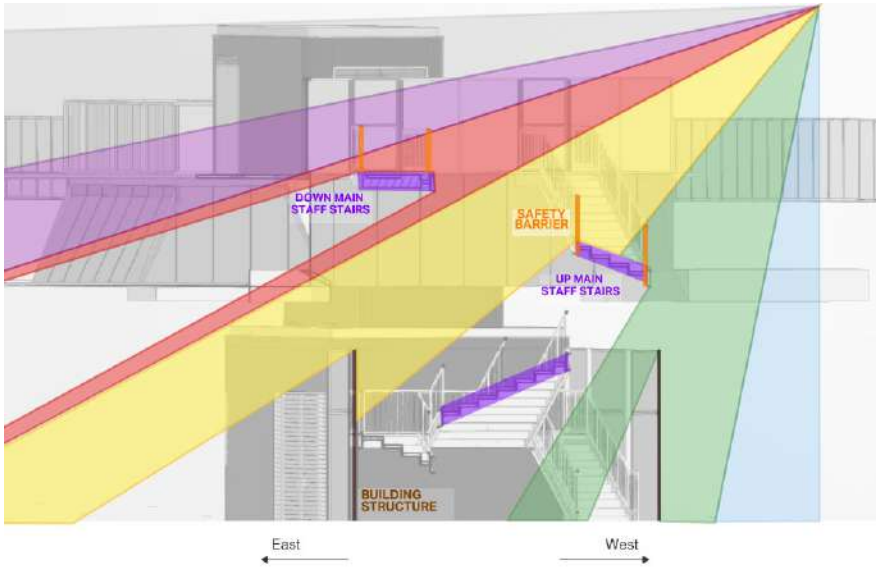


FIGURE 3-20 PLATFORM EGRESS STAIRS WESTERN RAIN ANGLES

Northern Rain

Figure 3-21 below analyses how Northern rain may impact the Public Pedestrian Stair with the cover of the overhanging canopy shell roof and perforated metal sheeting.

From this assessment, the overhanging roof with a 5m extension over the platform edge and the perforated metal sheeting are expected to provide some protection against rain from the North, but not complete protection to the Public Pedestrian Stair (where the screening is perforated). However, this will only occur for a small percentage of the year that it rains (noting it rains for only 7% of the year, based on past weather data from Jandakot Weather Station).

Note that environmental comfort studies assess general conditions and cannot evaluate the perforated screening's specific effects.

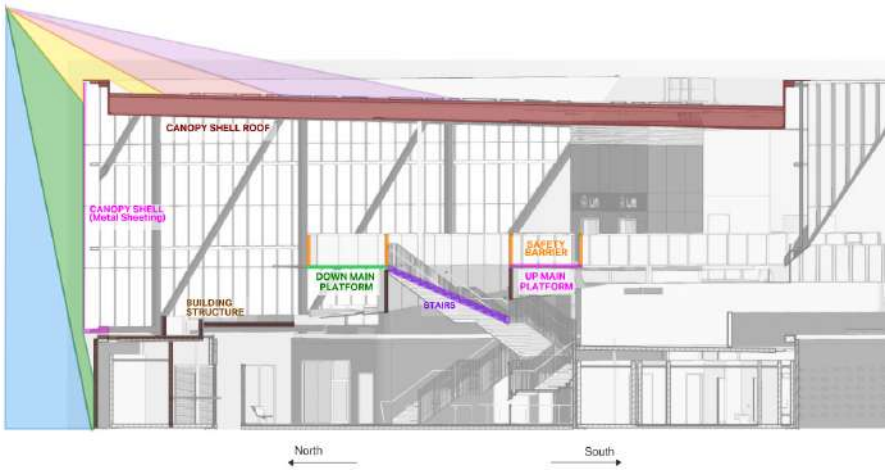


FIGURE 3-21 PLATFORM PEDESTRIAN STAIRS NORTHERN RAIN ANGLES

Figure 3-22 demonstrates that the Northern rain may penetrate the full depth of the Platform Egress Stairs depending on the rainfall angle.

Due to the exposed design and lack of protection, the Northern rain will have an impact on the Platform Egress Stairs, however, this will only occur for the small percentage of the year that it rains (noting it rains for only 7% of the year, based on past weather data from Jandakot Weather Station).

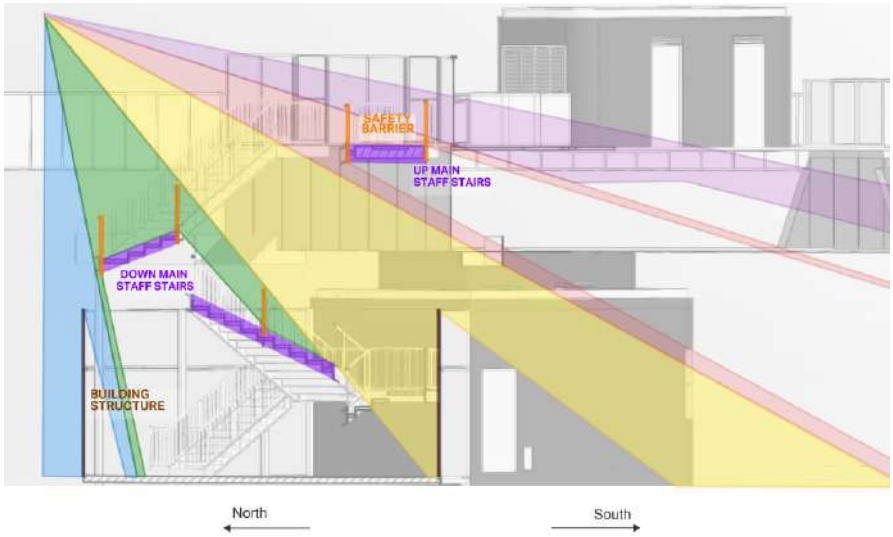


FIGURE 3-22 PLATFORM EGRESS STAIRS NORTHERN RAIN ANGLES

3.3.3.5 Escalator

Western Rain

Figure 3-23 below analyses how Western rain may impact the Escalator with the cover of the overhanging canopy shell roof, platform canopy and safety barrier along the escalator.

Rain from the West direction at 9.5m high will most likely fall at the red and yellow rain angles as identified by the percentage above in section 3.3.1. The escalators are impacted by the red rainfall angle, with this rainfall angle typically occurring for 26.5% of the time that it is raining from the West (less than approximately 1.7% of the time annually).

The Escalator may therefore be impacted by Western rain for a small percentage of the year depending on the rainfall angle.

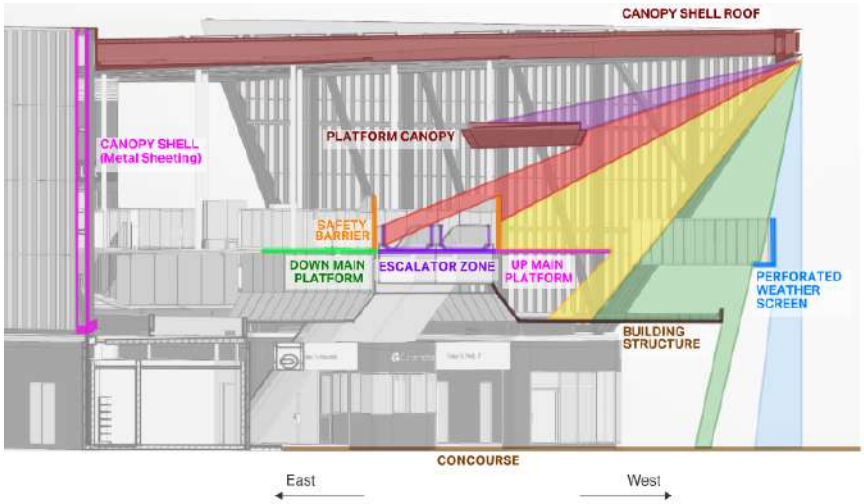


FIGURE 3-23 PLATFORM ESCALATOR WESTERN RAIN ANGLES

Northern Rain

Figure 3-26 below analyses how Northern rain may impact the Escalator Zone with the cover of the overhanging canopy shell roof, platform canopy and safety barrier along the escalator.

From this assessment, the impact to the Escalator Zone from Northern rain is expected to be minor. Rain from the North direction at 9.5m high will most likely fall at the green and yellow rain angles as identified by the percentage above in section 3.3.1. The escalators are impacted by the red rainfall angle. The areas encompassed by the red rain angles typically occur for 10.3% of the time that it is raining from the North (less than 1% of the time annually).

The Escalator may therefore be impacted by Northern rain for a very small percentage of the year depending on the rainfall angle.

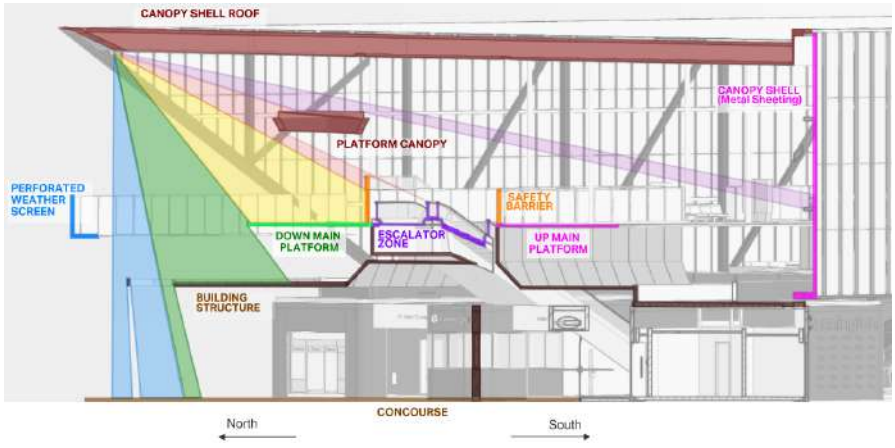


FIGURE 3-24 PLATFORM ESCALATOR NORTHERN RAIN ANGLES

3.3.3.6 Station Entry and Foyer

Western Rain

Figure 3-25 demonstrates the assessment location of ground floor concourse station entry and the two separate entryways. The North Station Entry is highlighted in green, and the South Station Entry is highlighted in pink.

FIGURE 3-25 GROUND FLOOR CONCOURSE STATION ENTRIES, NORTH (GREEN) AND SOUTH (PINK)

Figure 3-26 demonstrates how Western rain may land on the North and South Station Entry and Foyer. The concourse entry in this design has the cover of the overhead platform and tracks denoted by the green, pink and purple markups respectively.

For the North and South Station Entry and Foyer, rain from the West direction will most likely fall at the yellow and green rain angles as identified by the percentages above in section 3.3.1. The roof of the concourse building, and overhead platform and tracks may provide some protection to the station entries. However, rain from the West direction may still impact the North and South Station Entry. The rain will most likely fall at the yellow and green rain angles with a cumulative rate of 70.5% (less than approximately 4.9% of the time annually).

FIGURE 3-26 WESTERN RAIN ANGLES ON NORTH (LEFT) AND SOUTH (RIGHT) STATION ENTRIES

Northern Rain

Figure 3-27 demonstrates how Northern rain may land on the North and South Station Entry and Foyer. The concourse entry in this design has the cover of the overhead platform and tracks denoted by the green, pink, and purple markups respectively.

For the North and South Station Entry and Foyer, rain from the North direction will most likely fall at the blue and green rain angles as identified by the percentages above in section 3.3.1. The roof of the concourse building, and overhead platform and tracks may provide some protection to the North and South Station Entries. However, rain from the North direction may still impact both entries. The rain will most likely fall at the blue and green rain angles with a cumulative rate of 82.3% (less than approximately 5.7% of the time annually).

FIGURE 3-27 NORTHERN RAIN ANGLES ON NORTH (LEFT) AND SOUTH (RIGHT) STATION ENTRIES

3.3.3.7 Ticketing Machines

Western Rain

As identified in Figure 3-26 above, it is unlikely rain from the West will impact the ticketing machines on the Northern corner of the station entry.

Northern Rain

Canopy cover has been provided to the ticketing machines as indicated in Figure 3-28 below. At the ticketing machines, rain from the North direction will most likely fall at the blue and green rain angles as identified by the percentages above in section 3.3.1. The rain will most likely fall at the blue and green rain angles with a cumulative rate of 82.3% (less than approximately 5.7% of the time annually). The additional canopy above the ticketing machines likely provides protection from both of these rainfall angles. Should the rain fall at a greater rainfall due to faster wind speeds, the ticketing machines may still be impacted for a small percentage of the time it is raining.

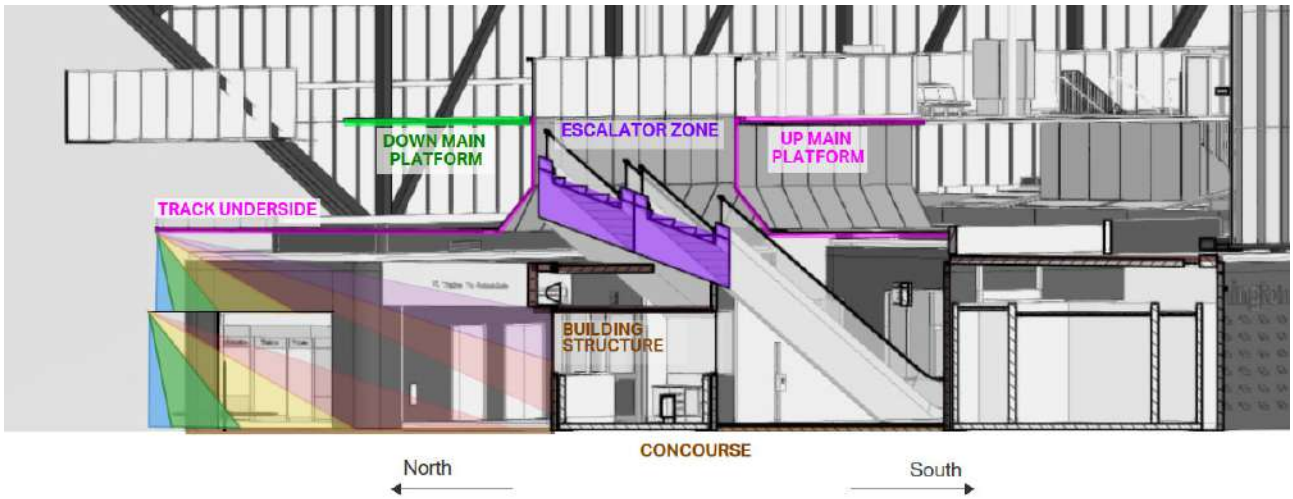


FIGURE 3-28 NORTHERN RAIN ANGLES ON TICKETING MACHINES (SECTION)

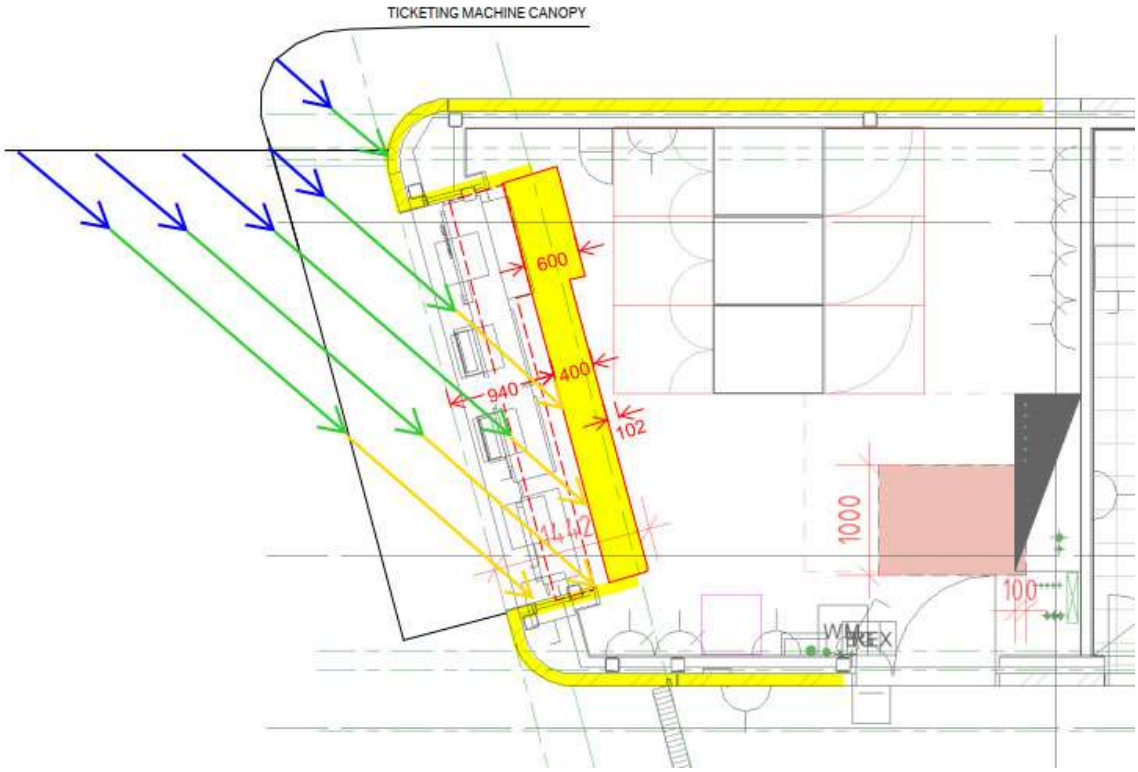


FIGURE 3-29 NORTHERN RAIN ANGLES ON TICKETING MACHINES (PLAN) – TICKETING MACHINES HIGHLIGHTED IN YELLOW

3.3.3.8 Bus Shelter

Western Rain

Figure 3-30 below analyses how Western rain may fall on the Bus Shelter area, while considering the rail corridors running above. From this assessment, some protection from the Western rain may be provided to commuters by the shelter canopies and the weather screens. For bus shelters where a weather screen is not installed, it is likely for the Western rain to penetrate the full depth of the shelter area. This is highlighted in the bottom image of Figure 3-30.

FIGURE 3-30 WESTERN RAIN ANGLES ON BUS SHELTERS THROUGH DOWN MAIN (TOP) AND UP MAIN (BOTTOM) RAIL CORRIDORS

Northern Rain

Figure 3-31 below analyses how Northern rain may fall on the Bus Shelter area, while considering the rail corridors running above. From this assessment, some protection from the Northern rain may be provided to commuters by the shelter canopies and the weather screens. However, the top image demonstrates that the shelters below the Down Main track maybe be considerably exposed to Northern rain. Additionally, it can be seen in the bottom image of Figure 3-31, that there is potential for Northern rain to penetrate under the full depth of the bus shelter in areas where no weather screen is installed.

FIGURE 3-31 NORTHERN RAIN ANGLES ON BUS SHELTERS THROUGH DOWN MAIN (TOP) AND UP MAIN (BOTTOM) RAIL CORRIDORS

3.4 Wind Protection

The aim of this analysis is to provide advice on the probable wind direction and its impact on waiting passengers on the platforms. The assessment is completed using average wind speeds and directions and is provided to analyse the comfort conditions for passengers. It does not consider safety risks such as wind gusts or wind tunnelling.

As a benchmark, Green Star Railway Stations v1.1 requires that wind breaks are provided which provide shelter from prevailing winds to at least 10% of the area of each platform through the use of structure or landscaping.

The Lawson[2] comfort criteria has been used in this assessment. The criteria are based on the probability of exceeding certain mean wind speeds. For passengers sitting or standing for a short period of time, the maximum comfortable wind speed is 6m/s. Refer to Appendix A for details on the calculation methods proposed.

3.4.1 Scope Item Comments

The table below identifies which scope items the wind protection assessment relates to and summarises the assessment findings.

[2] Lawson, T. (1978). The Wind Content of the Built Environment. Journal of Wind Engineering and Industrial Aerodynamics, Volume 3, Issues 2-3, 93-105

TABLE 3-10 - SCOPE ITEMS ADDRESSED

Scope Item	Comments
22.1-197 (i)	*The NOP shall ensure the cover at each new station at a minimum:* *i) Prevents prevailing weather from impacting on Station Entry(s) and Station Foyer(s)* The prevailing wind direction and average speeds have been assessed in section 3.4.2 below. **Station Entry and Foyer:** In line with the Lawson comfort criteria, the average wind speeds from the prevailing wind directions are considered comfortable for passengers sitting or standing for short periods of time.
22.4-5-3-18	*Wind study demonstrating that the design of stations entry buildings and platforms enables comfortable and safe conditions.* Note that wind safety is not covered within this report. **Station Entry and Foyer:** As identified above, in line with the Lawson comfort criteria, the average wind speeds from the prevailing wind directions are considered comfortable for passengers sitting or standing for short periods of time. **Platforms:** In line with the Lawson comfort criteria, the average wind speeds from the prevailing wind directions are considered uncomfortable for passengers sitting or standing for short periods of time. However, some protection may be provided via infrastructure on the platform (i.e., staff office, comms room and perforated screening). It is noted that the perforated screening will not provide full protection. These objects may provide some protection from the prevailing winds for more than 10% of the platform, meeting the Green Star Railway v1.1. best practice requirements. The canopy shell may also provide some protection from the prevailing winds to the section of the platform it envelops, however the screen is permeable and may not provide full protection.
22.4.5-3-20	*Environmental assessment including solar access and control, wind protection, rain protection, natural lighting; solar reflection; natural ventilation.* Note that natural ventilation is not included within this NOA and will be covered by the mechanical engineering design team. Refer to 22.4-5-3-18 above.
PTA Specification 6.12	*The platform canopy length shall:* *Extend for a minimum of 15 metres beyond the end of the vertical transportation on the platform.* Due to the glass adjacent to the lifts, there is some protection from the prevailing winds at each lift entry. An extended canopy is not expected to provide additional protection from the wind without a vertical element to the canopy, as the passengers would be exposed to wind underneath the canopy.

3.4.2 Assessment Results

As mentioned in Section 2.4, in line with the SWTC environmental comfort scope, the below listed assessment areas of both platforms and the station building were identified for rain protection:

- Platform (Section □)
- Station Entry and Foyer (Section 3.4.2.2)

The analysis determined that there are three prevailing wind directions at Jandakot. Note that the three prevailing winds are different to the wind directions included in the rain assessment as the prevailing winds include winds at all times of the year (the rain assessment considers wind only when it is raining). The three prevailing winds are:

- East (100° to 110°) accounting for 11.2% of the year
- South (180° to 190°) accounting for 9.6% of the year
- South West (220° to 240°) accounting for 12.7% of the year

3.4.2.1 Platforms

Figure 3-32 indicates that the section of platform that extends beyond the cover of the canopy shell is relatively exposed for each of the prevailing wind directions. Some protection may be provided via infrastructure on the platform (i.e. staff office, comms room and glass screening), provided the screening is not permeable. The canopy shell may provide some protection from the prevailing winds to the section of the platform it envelops, however the screen is permeable and may not provide full protection.

The wind, from all directions, at the platform height will be considered uncomfortable according to the Lawson comfort criteria. It will not be uncommon for wind speeds up to 9m/s to be experienced from the Southwest and Eastern directions.

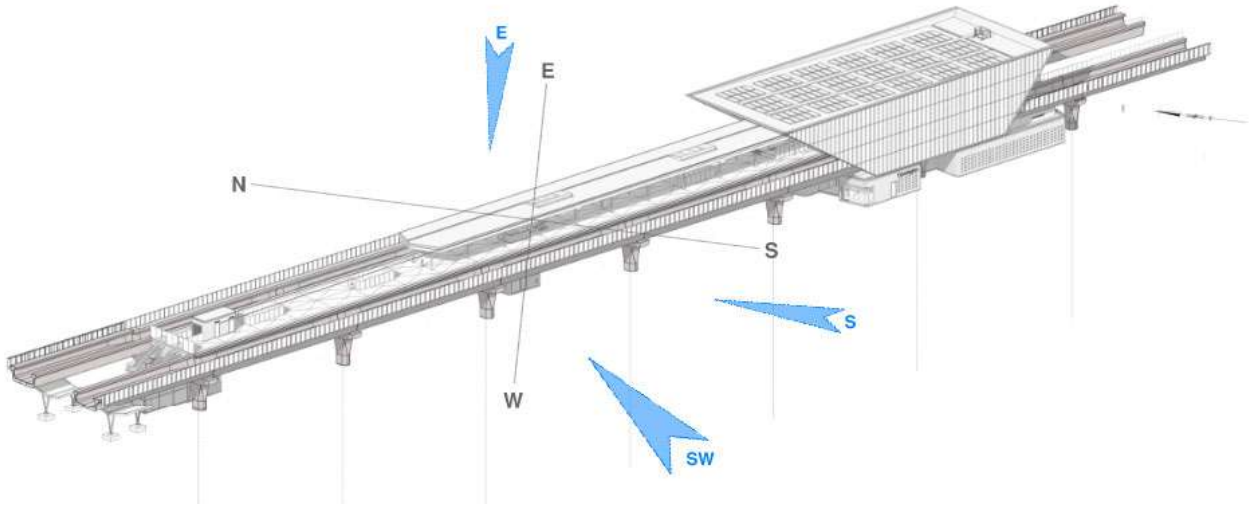


FIGURE 3-32 PREVAILING WIND DIRECTIONS ON PLATFORM LEVEL

Table 3-11 below summarises the prevailing wind directions on platform level, protection mechanisms and whether the wind speed is acceptable under the Lawson comfort criteria.

TABLE 3-11 PREVAILING WIND DIRECTION AND PROTECTION MECHANISMS ON PLATFORM LEVEL

Prevailing Wind Direction	Percent of Annual Hours with Wind	Acceptable Wind Speed per Lawson criteria?	Wind Protection provided to uncomfortable wind?	Protection Mechanism
East	11.2%	No	Yes	Staff office, comms room, perforated

Prevailing Wind Direction	Percent of Annual Hours with Wind	Acceptable Wind Speed per Lawson criteria?	Wind Protection provided to uncomfortable wind?	Protection Mechanism
				screening. Some protection from canopy shell.
South	9.6%	No	Yes	Staff office, comms room, perforated screening. Some protection from canopy shell.
Southwest	12.7%	No	Yes	Staff office, comms room, perforated screening. Some protection from canopy shell.

3.4.2.2 Station Entry and Foyer

Figure 3-33 demonstrates how the prevailing wind directions may affect the concourse station entrance. The entrance could see crosswind from Southwest and East prevailing winds. However, typically the wind from each of these directions are at a comfortable speed, in accordance with the Lawson comfort criteria.

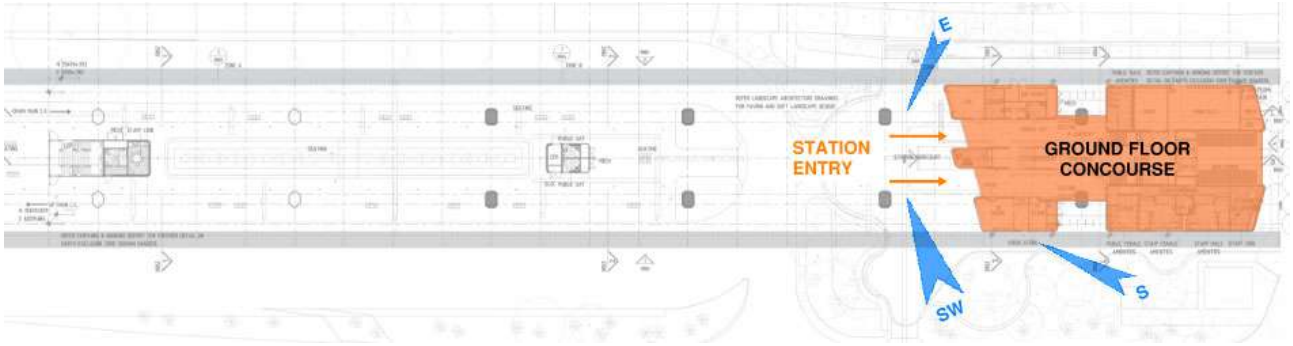


FIGURE 3-33 PREVAILING WIND DIRECTIONS ON GROUND FLOOR CONCOURSE LEVEL

Table 3-12 below summarises the prevailing wind directions on ground level, protection mechanisms and whether the wind speed is acceptable under the Lawson comfort criteria.

TABLE 3-12 PREVAILING WIND DIRECTION AND PROTECTION MECHANISMS ON GROUND LEVEL

Prevailing Wind Direction	Percent of Annual Hours with Wind	Acceptable Wind Speed per Lawson criteria?	Wind Protection provided to uncomfortable wind?	Protection Mechanism
East	11.2%	Yes	Potential cross wind	-
South	9.6%	Yes	Yes	-
Southwest	12.7%	Yes	Potential cross wind	Station building

3.5 Natural Lighting

The aim of this analysis is to provide advice on probable natural daylight access to regularly occupied spaces. An indoor environment that achieves good daylight amenity improves health and wellbeing and boosts productivity. Therefore, ensuring internal spaces in the station are provided with good access to daylight is beneficial to both the staff and passengers.

The natural lighting assessment is calculated in line with the Green Star Daylight and Views Hand Calculation Guide. As a benchmark, Green Star requires 50% of the total primary space (areas where a person is expected to work or remain for an extended period of time such as ticket counters, offices and retail areas) to achieve good daylight amenity. Refer to Appendix A for details on calculation methods proposed.

3.5.1 Scope Item Comments

TABLE 3-13 - SCOPE ITEMS ADDRESSED

Scope Item	Comments
22.4.5-3-20	*Environmental assessment including solar access and control, wind protection, rain protection, natural lighting; solar reflection; natural ventilation.* Note that natural ventilation is not included within this NOA and will be covered by the mechanical engineering design team. A daylight amenity assessment has been completed in section 3.5.2 below. The assessment determined that the Customer Services Office, the staff office and more than 90% of the kiosk will have good access to natural light, meeting best practice requirements as per Green Star Railway Stations v1.1. The Shared Staff Crib currently does not meet best practice requirements as defined by Green Star Railway Stations v1.1, as it receives good daylight access for less than 50% of the area. For improved daylight access, each occupied primary space should ensure a VLT of greater than 40% to all glazing.

3.5.2 Assessment Results

As mentioned in Section 2.4, in line with the SWTC environmental comfort scope, there are three qualifying assessment areas (i.e., areas where a person is expected to work or remain for an extended period of time) in the Southernmost concourse building where people may spend a considerable amount of time including:

- Customer Services Office (CSO) (Section 3.5.2.1)
- Shared staff crib (Section 3.5.2.2)
- Kiosk (Section 3.5.2.3)
- Staff Office (Section 3.5.2.4)

3.5.2.1 CSO

The CSO has an approximate floor area of 16m^2 and has approximately 1.6m tall windows around the perimeter of the office (approximately 11.5m long). Applying the Green Star Hand Calculation approach, all of the CSO will have good access to natural light as per the requirements of Green Star Railway Stations v1.1. Ensure glazing has a VLT of greater than 40%.

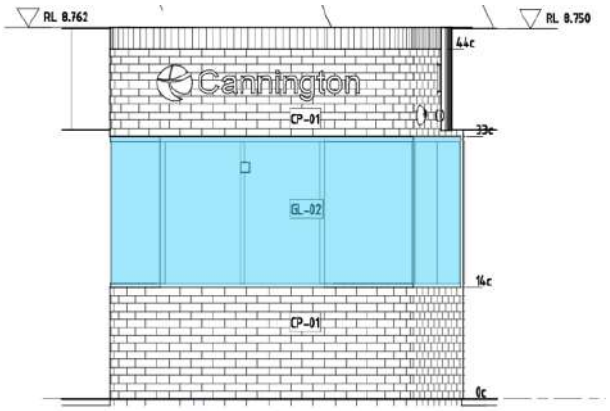


FIGURE 3-34 ELEVATION OF CSO

3.5.2.2 Shared Staff Crib

The shared staff crib has an approximate floor area of 32m^2 has 1.6m tall windows, on the Southern edge of the concourse (3.5m long). Applying the Green Star Hand Calculation approach, less than 50% of the Staff Crib (approximately 35%) will have access to natural light (not meeting Green Star best practice requirements).

However, while the room does not meet best practice daylight requirements, it is noted by the ALUA Green Star Accredited Professional that for the Cannington Station Green Star rating the Shared Staff Crib has been excluded from the primary space requirements as staff will be in there for a limited time. Ensure glazing has a VLT of greater than 40%.

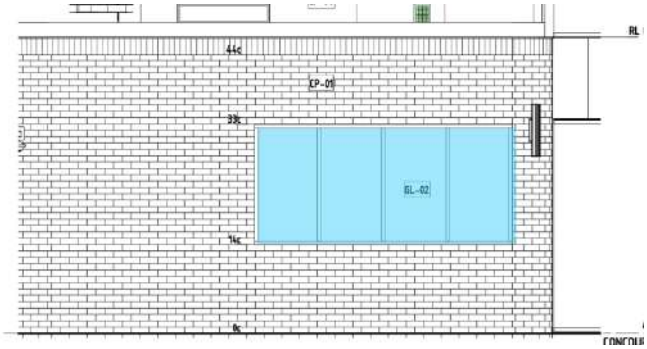


FIGURE 3-35 ELEVATION OF THE SHARED STAFF CRIB FROM THE SOUTH-EAST

3.5.2.3 Kiosk

The kiosk has an approximate floor area of 27m^2 has 2.7m tall windows (2.0m above desktop height, i.e. 700mm) on the Southern edge of the concourse (6.3m long). Applying the Green Star Hand Calculation approach, more than 90% of the Kiosk will have access to natural light (meeting Green Star best practice requirements). Ensure glazing has a VLT of greater than 40%.

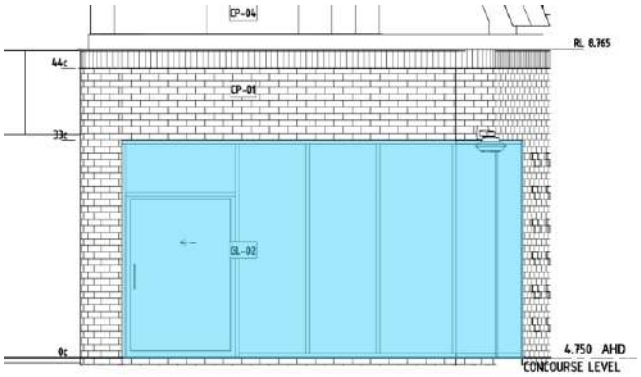


FIGURE 3-36 ELEVATION OF THE KIOSK

3.5.2.4 Staff Office

The staff office has an approximate floor area of 11m^2 has 1.4m tall windows (around the perimeter of the office). Applying the Green Star Hand Calculation approach, all of the office will have access to natural light (meeting Green Star best practice requirements). Ensure glazing has a VLT of greater than 40%.

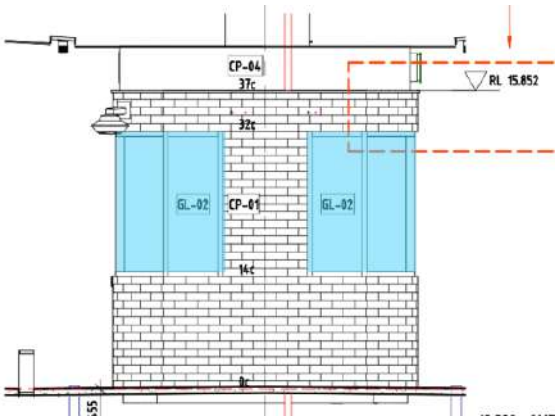


FIGURE 3-37 ELEVATION OF THE STAFF OFFICE

Appendix A

PREVIOUS ASSESSMENTS

Appendix B

PTA MEETING MINTUES

Appendix C
METHODOLOGY

Green Star for Railway Stations

Where applicable, the Green Star – Railway Stations v1.1 tool has been used as a benchmark to gauge whether the current designs provide suitable comfort strategies for commuters and staff. Green Star is an internationally recognised rating system that assesses best practice sustainability outcomes throughout the life cycle of the built environment. The Green Star – Railway Stations v1.1 tool is a customisation of Green Star – Design & As Built v1.2 tool and has been prepared for use on above ground and underground railway stations.

Solar Access, Natural Lighting and Glare

Figure 3-38 below shows the sun path diagram for Perth obtained from www.gaisma.com. The sun path diagram is a useful tool that shows the path a sun takes as it travels from East to West across the year, which is highlighted in yellow in the figure. The directions where the sun is shining from is indicated by the angles on the circumference on the circle and the altitude of the sun is indicated by the concentric circles. The lines bounding the annual variation zone (yellow), the green line and blue line, denote the path of the sun when travelling across the June (winter) solstice and December (summer) solstice, respectively. The autumn and spring equinox line (grey) indicates the two times each year where the centre of the sun crosses the plane of the earth's equator and the day and night are of equal length.

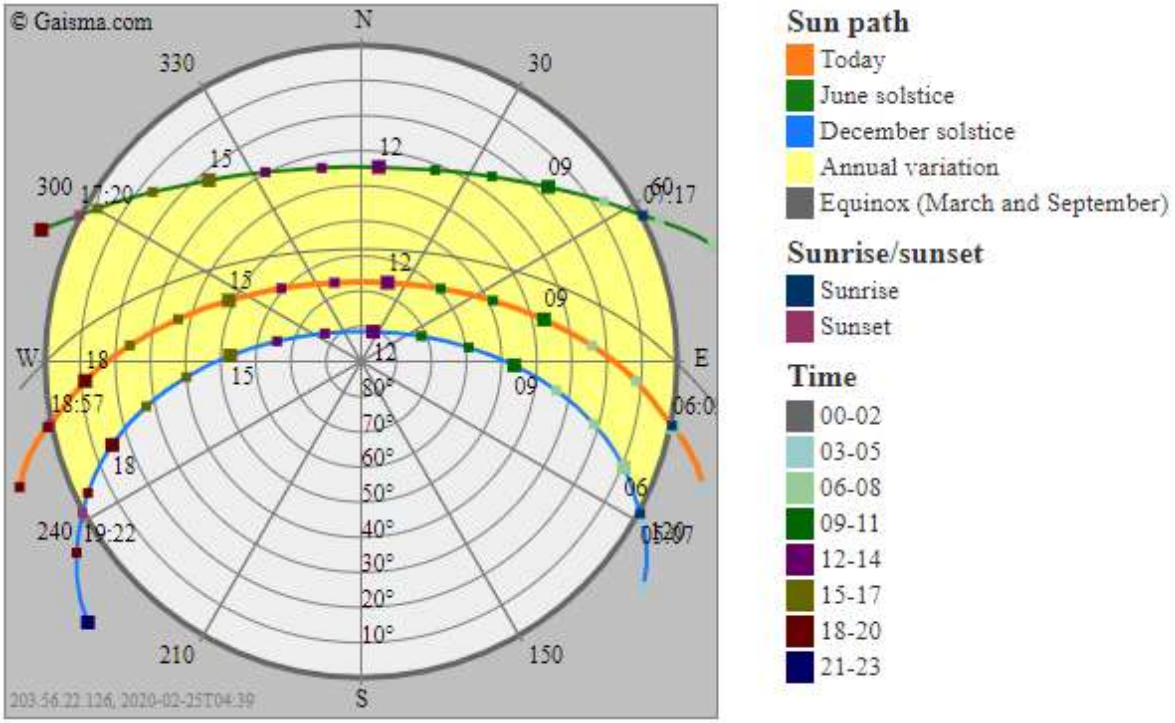


FIGURE 3-38 PERTH SUN PATH DIAGRAM

The sun path indicates that the sun in Perth will mostly be coming from the North direction (angles 270° to 90° on the circumference) except for during the summer months where it is possible for the sun to shine from the Southeast directions at dawn and from the Southwest direction at dusk.

Figure 3-39 below provides an explanation on the difference between sun angle and altitude. The sun angle refers to the compass direction from which the sunlight is coming, whereas the sun altitude refers to the angle of the sun relative to the earth's horizon.

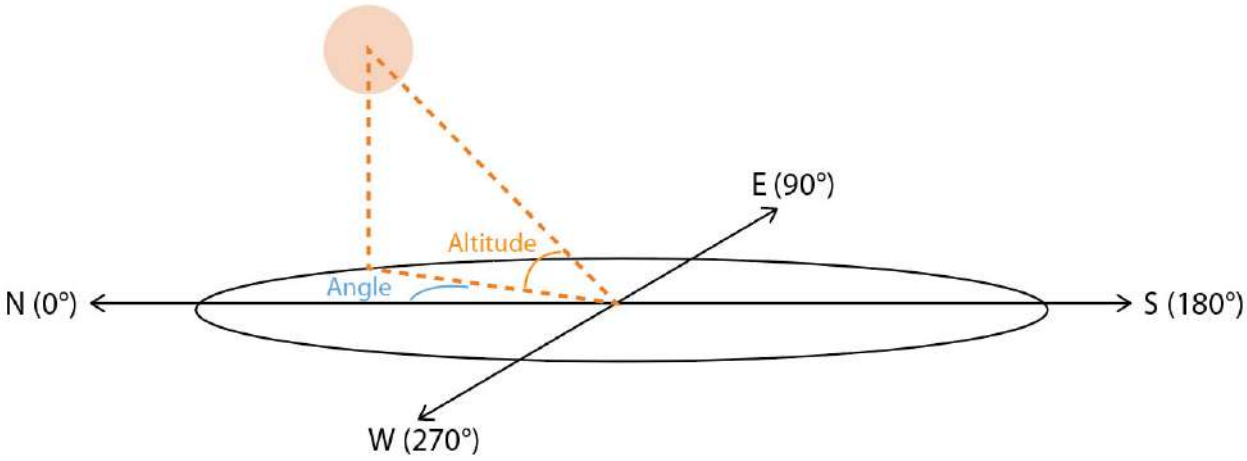


FIGURE 3-39 DEFINITION OF SUN ANGLE AND ALTITUDE

Table 3-14 below indicates the sun altitude, azimuth angle and shadow length for both the summer and winter solstice, as well as the autumn and spring equinoxes. Three timeframes have been shown, 2pm, 4pm and 6pm, representing the peak heat of the afternoon. Shadow length refers to the length of solar shade in meters, for an object of 1m in height.

TABLE 3-14 SUN ANGLES AND ALTITUDE DURING AFTERNOON PEAK PERIOD

Time	2pm	4pm	6pm
Summer Solstice (21 December)	Altitude: 65.90° Azimuth Angle: 284.25° Shadow length: 0.45m	Altitude: 40.62° Azimuth Angle: 265.25° Shadow length: 1.17m	Altitude: 15.58° Azimuth Angle: 251.74° Shadow length: 3.59m
Autumn Equinox (20 March)	Altitude: 51.34° Azimuth Angle: 321.29° Shadow length: 0.80m	Altitude: 30.48 Azimuth Angle: 291.62° Shadow length: 1.70m	Altitude: 5.59° Azimuth Angle: 273.53° Shadow length: 10.21m
Winter Solstice (21 June)	Altitude: 29.84° Azimuth Angle: 333.84° Shadow length: 1.74m	Altitude: 13.95° Azimuth Angle: 309.58° Shadow length: 4.02m	Sunset
Spring Equinox (22 September)	Altitude: 49.06° Azimuth Angle: 316.26° Shadow length: 0.86m	Altitude: 27.54° Azimuth Angle: 289.08° Shadow length: 1.92m	Altitude: 2.59° Azimuth Angle: 271.52° Shadow length: 22.07m

Source: www.suncalc.org

Solar Access and Control

The solar access and control assessments are completed by simply using the sun's angle and altitude to determine which areas of the platform and concourse are shaded at certain times of the day.

Two time frames are assessed, in line with Green Star Railway Stations v1.1 (2pm and 6pm). As Green Star requires 20% of the platform to be shaded for the afternoon peak period during the warmest half of the year the sun angles will be assessed between the spring and autumn equinox (including the summer solstice).

An example of this is provided in Figure 3-40 and Figure 3-41 below. Figure 3-40 shows that at 2pm and 6pm the canopy some portions of the platform receive solar exposure. Figure 3-41 shows that while the canopy protect the Up Main platform from an elevation perspective, due to the sun angle coming from the

Northwest in autumn and spring, the platform is actually relatively exposed at this time. However, during summer the metal screen in the canopy provides protection.

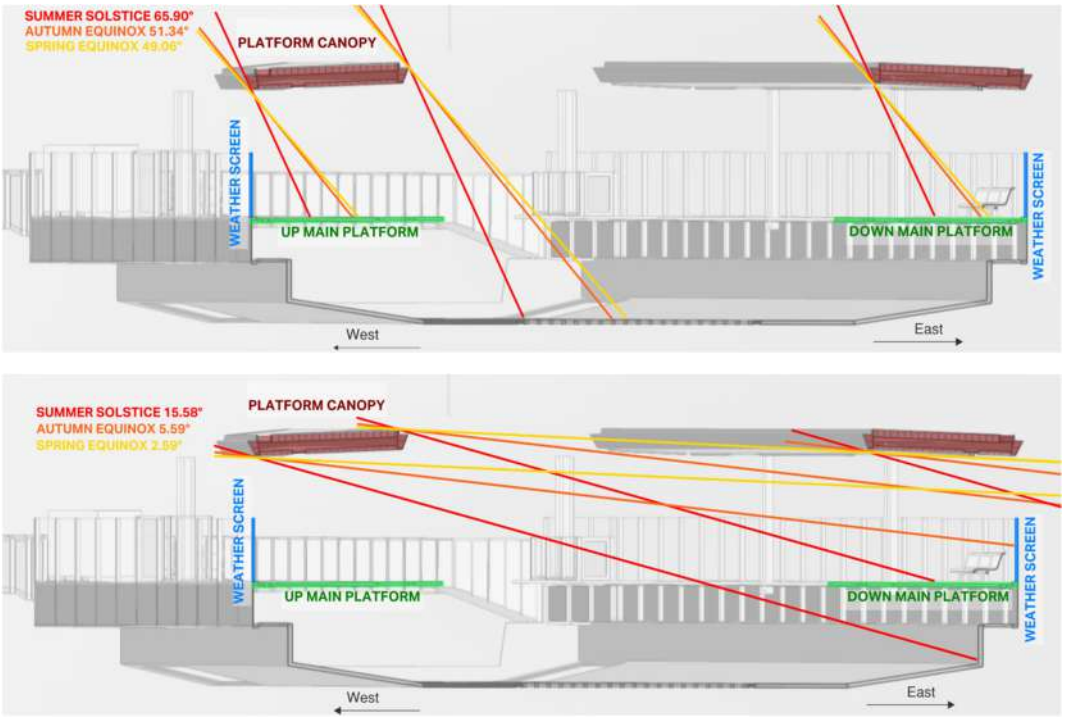


FIGURE 3-40 SUN ALTITUDE AT 2PM (TOP) AND 6PM (BOTTOM)

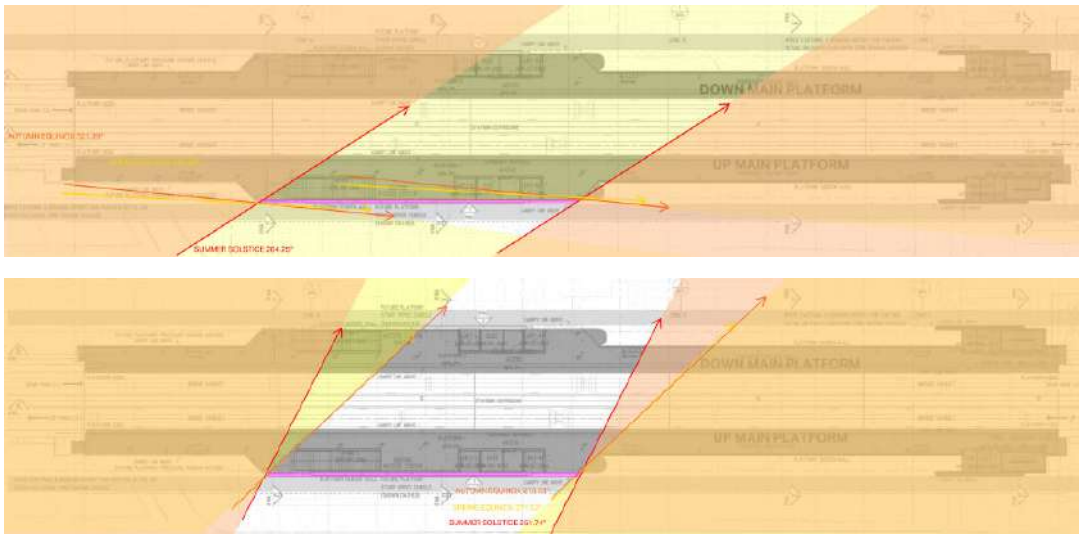


FIGURE 3-41 SUN AZIMUTH ANGLE AT 2PM (TOP) AND 6PM (BOTTOM)

Natural Lighting

An indoor environment that achieves good daylight amenity improves health and wellbeing and boosts productivity. Therefore, ensuring internal spaces in the station are provided with good access to daylight is beneficial to both the staff and passengers.

The natural lighting assessment is calculated in line with the *Green Star Daylight and Views Hand Calculation Guide*. As a benchmark, Green Star requires 50% of the total primary space (areas where a person is expected to work or remain for an extended period of time such as ticket counters, offices and retail areas) to achieve good daylight amenity.

The Green Star Daylight and Views Hand Calculation Guide assumes that there is no significant loss of light due to external obstructions or interior screening.

The zone that is expected to achieve good daylight amenity is calculated as the area (in the horizontal plane) that is equal to the width of the window by a depth that is twice the height of the window head above desktop/ table level. This is illustrated in Figure 3-42 below.

Depth of expected good daylight amenity = 2 x h

'w' width of expected good daylight amenity = width of the glazing

Area of expected good daylight amenity = 2 x h x w

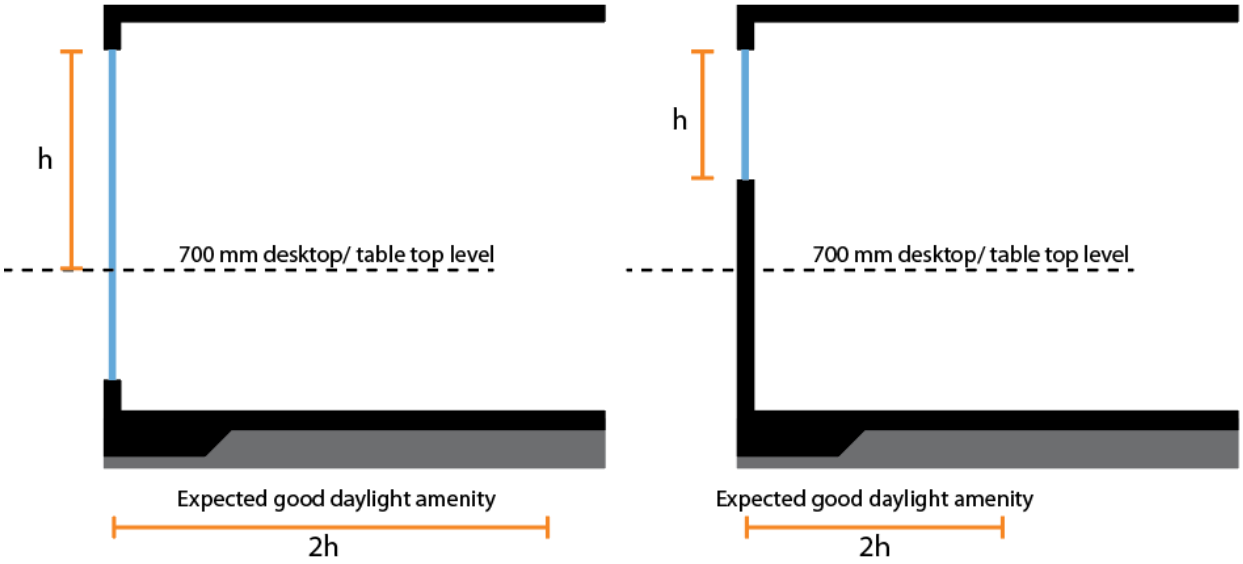


FIGURE 3-42 EXPECTED GOOD DAYLIGHT AMENITY DIAGRAM

The area of expected good daylight amenity can then be compared to the area of the primary space. The area of expected good daylight amenity should make up more than 50% of the primary space area.

Solar Reflection

The glare analysis is completed by simply using the sun's angle and altitude to highlight any areas prone to risk of solar reflection impacting the train driver's vision.

An example is provided in Figure 3-43 below where the sun path for Perth is overlaid on a station platform. In this example, the sun path diagram indicates the following:

- In the early hours of the morning, the sun will be at a low altitude and angled towards the East. Therefore, the sun could potentially reflect off any shiny surfaces under the canopy shell of the Up Main Platform to the East, impacting train drivers on both train lines and/or passengers on the Down Main Platform.
- In the late evening, the sun will be at a low altitude and angled towards to the West. Therefore, the sun could potentially reflect off any shiny surfaces under the canopy shell of the Down Main Platform to the West and impact train drivers on both train lines and/or passengers on the Up Main Platform.

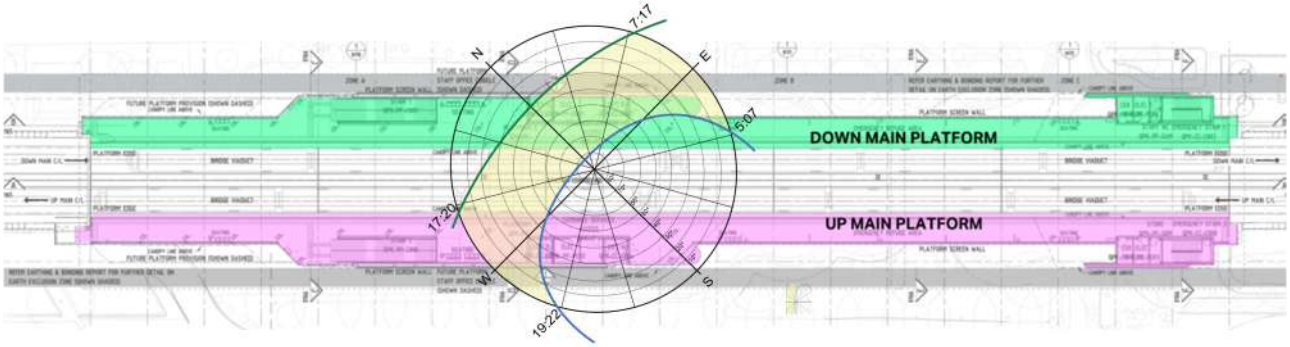


FIGURE 3-43 SUN PATH DIAGRAM

Rain Analysis

The purpose of the rain analysis is to provide advice on the probable rainfall angle and its impact on waiting passengers on the newly proposed platforms. The methodology for this assessment includes the calculation of likely wind speed, direction, and the size and mass of the rainfall droplets. The methodology for this is detailed below.

As a benchmark, Green Star – Railway Stations v1.1 requires that 80% of the platform should be protected from rain for stations with high peak occupancy. Stations with high peak occupancy refers to stations where morning and afternoon commuting passengers regularly fill the platform.

Rain Angles

To calculate the resultant rain angle (θ), the forces acting on the water droplet must be considered, as demonstrated in Figure 3-44 below. These forces include both gravitational force and the force of the wind, calculated from wind direction and speed. The resultant drag force has not been included, as this will be acting in the direction of the droplet movement, and will therefore not affect the rain angle. It is assumed that the wind direction is not affected by local obstructions near the train station and that raindrops can be assumed to be spherical in shape.

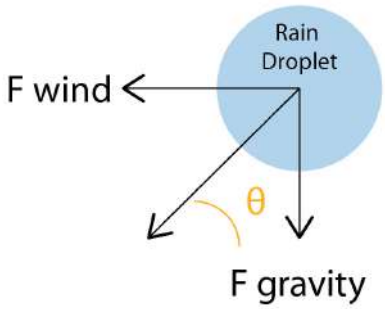


FIGURE 3-44 FORCES ACTING ON THE WATER DROPLET, EXCLUDING DRAG FORCE

Wind Pressure Force

The wind pressure force acting in the direction of the wind is shown below in Equation 1.

$$F_{wind} = \frac{1}{2}\rho_{air}U^2A$$

EQUATION 1 WIND PRESSURE FORCE

Where:

- F_{wind} is the wind pressure force in Newtons
- ρ_{air} is the air density, taken as 1.2kg/m^3
- U^2 is the wind speed at occupant height
- A is the area of the droplet facing the wind in m^2, related to the droplet size

Gravitational Force

The gravitational force acting in the direction of the wind is shown below in Equation 2.

$$F_{gravity} = \rho_{water}Vg$$

EQUATION 2 GRAVITATIONAL FORCE

Where:

- $F_{gravity}$ is the gravitational force in Newtons
- ρ_{water} is the water density, taken as 1,000kg/m3
- V is the droplet volume in m3, related to the droplet size
- g is the gravitational acceleration, 9.81 m/s2

Rain Droplet Size

Several studies have been completed on raindrop size distribution, most notably the Marshall Palmer study in 1948. This study derives an exponential correlation between the number of raindrops per cubic meter of air and the raindrop diameter. This study compares well with the Laws and Parsons study, completed in 1943; and rainfall observations in Ottawa in the summer of 1946 for diameters of 1.5mm and above. There is not sufficient resolution for raindrop sizes less than 1.5mm; and this should be considered a limitation of the study.

Tom Lawson in Building Aerodynamics (2001) has proposed a more recent equation for the distribution of raindrops based on raindrop diameter, shown in Equation 3 below. This creates a non-exponential correlation for smaller raindrop diameters, which allows for an estimation of the most frequent raindrop sizes.

$$\frac{dR}{dD} = 49.25 \times D^{3.5} e^{(-4.1 \times R^{-0.222} \times D)}$$

EQUATION 3: LAWSON DISTRIBUTION OF RAINDROP SIZES

Where:

- R is the rain rate (mm/hour)
- D raindrop diameter in mm
- $\frac{dR}{dD}$ is the contribution to the rainfall intensity R

Rain Rate

The rain rate (mm/hour) was determined based on the Intensity-Frequency-Duration (IFD) Design Rainfall Depth for Perth over 1 hour, provided by the Australian Bureau of Meteorology[3]. For this analysis, two rainfall rates were chosen: the 50th percentile and 95th percentile. These represent the rain rates which are exceeded for 50% and 5% of all rain events annually respectively. This provides a distribution of the raindrop diameters for the median rainfall and rainfall for the near-highest recorded events.

The 50th percentile and 95th percentile rain rates for Perth were found to be 18.7mm/hour and 32.5mm/hour, respectively.

Applying the Lawson distribution of raindrop sizes as per Equation 3, the probability distribution for different droplet diameters was plotted. This is shown below in Figure 3-45.

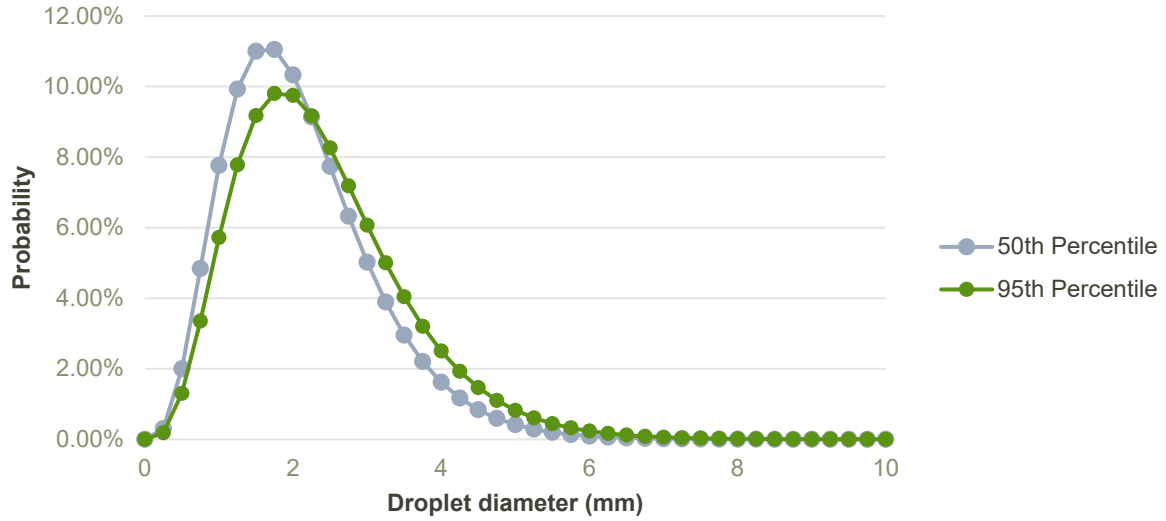


FIGURE 3-45 PROBABILITY DISTRIBUTION OF RAINDROP SIZES BASED ON LAWSON (2001) DISTRIBUTION

Based on the rainfall distribution shown in Figure 3-45, the droplet diameter with the highest probability is estimated at 1.75mm in diameter for both the 50th percentile and 95th percentile rainfall rates.

[3] http://www.bom.gov.au/water/designRainfalls/revised-ifd/?coordinate_type=dd&latitude=-31.9505&longitude=115.8605&user_label=&year=2016&design=ifds&sdmin=true&sdhr=true&sdday=true

The most common droplet size for the 50th percentile and 95th percentile rain rate will be used in conjunction with the wind analysis to calculate the rainfall angle as described in Section 3.3.

The distribution shown in Figure 3-45 also indicates that:

- Approximately 10% (95th percentile) to 15% (50th percentile) of the droplets will be 1mm in diameter or less
- Approximately 47% (95th percentile) to 57% (50th percentile) of the droplets will be 2mm in diameter or less
- Approximately 78% (95th percentile) to 85% (50th percentile) of the droplets will be 3mm in diameter or less
- Approximately 92% (95th percentile) to 96% (50th percentile) of the droplets will be 4mm in diameter or less

This gives an estimate on the amount of rain that will be able to pass through different opening sizes for any porous material used for the walls enclosing the concourse or platform, e.g. an average opening size of 2mm would result in approximately 50% of the rain passing through.

Meteorological Data Analysis

To determine the wind velocity at the platform, wind data was obtained from the Bureau of Meteorology for three different stations (Jandakot and Perth Metro) for an approximately 15 year period from the year 2005.

The different weather stations, and their relationship to the Victoria Park-Canning Level Crossing Removal Program stations are presented in the figure below.

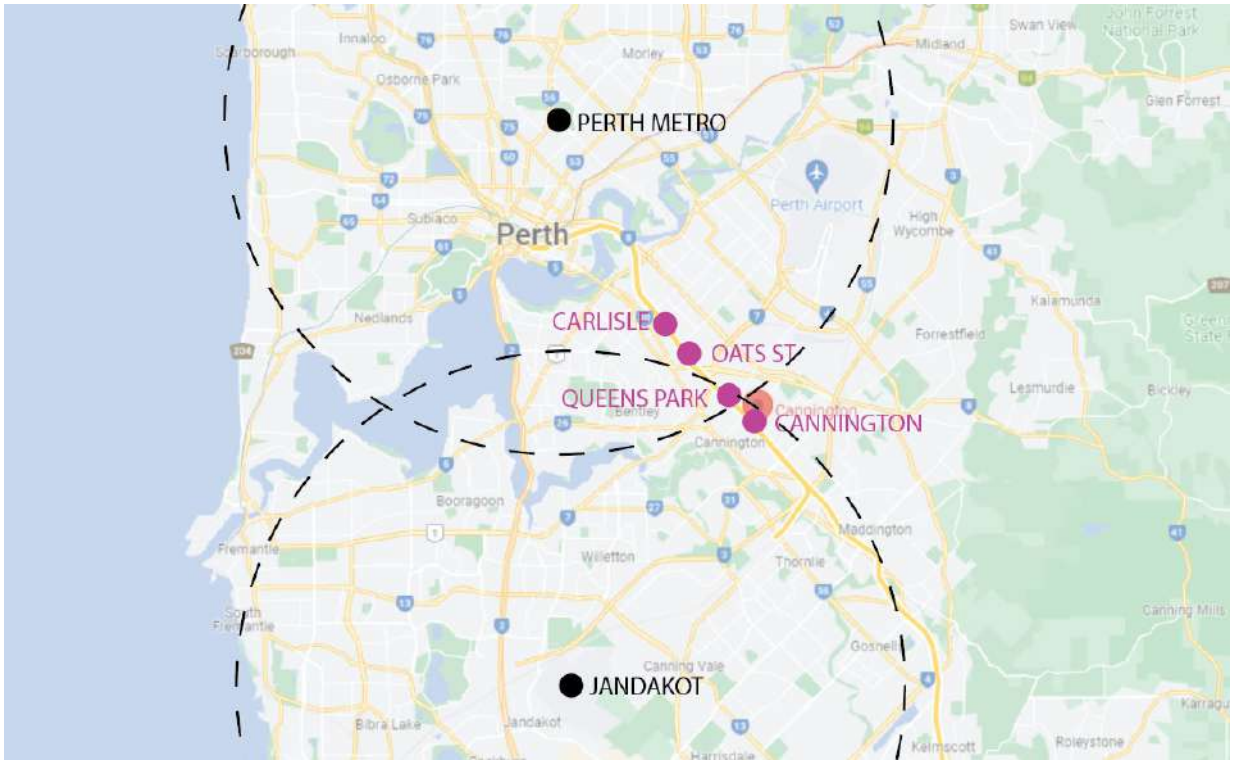


FIGURE 3-46 WEATHER STATION (BLACK) AND STATIONS (PINK)

The data is presented in 10-minute averages for each hour. Wind data from the weather station is assumed to be at 10m high, based on the typical anemometer height. A logarithmic profile was used to calculate the wind speeds at occupant height.

The data was further filtered to exclude hours where there is no precipitation.

Jandakot

In Jandakot, the mean annual rainfall is 818.4mm and it rains for 7% of the year.

Table 3-15 and Table 3-16 below show the times of year and the time of day when it is likely to rain. The tables indicate:

- The majority (54%) of rainfall occurs in winter
- The time of day at which rainfall occurs is evenly distributed throughout the day

TABLE 3-15 FREQUENCY OF RAINFALL BASED ON SEASON

Period	Months	Occurrence
Summer	Dec - Feb	7%
Autumn	Mar - May	20%
Winter	Jun - Aug	54%
Spring	Sep - Nov	19%

TABLE 3-16 FREQUENCY OF RAINFALL BASED ON TIME

Period	Time	Occurrence
Night	0:00 - 06:00	27%
Morning	06:00 - 12:00	24%
Afternoon	12:00 - 18:00	23%
Evening	18:00 - 24:00	26%

Figure 3-47 below shows that when rain is falling, there are two prevailing wind directions:

- West (240° to 300°) accounting for 36.8% of the annual hours when precipitation occurs
- North (10° to 20°) accounting for 9.7% of the annual hours when precipitation occurs

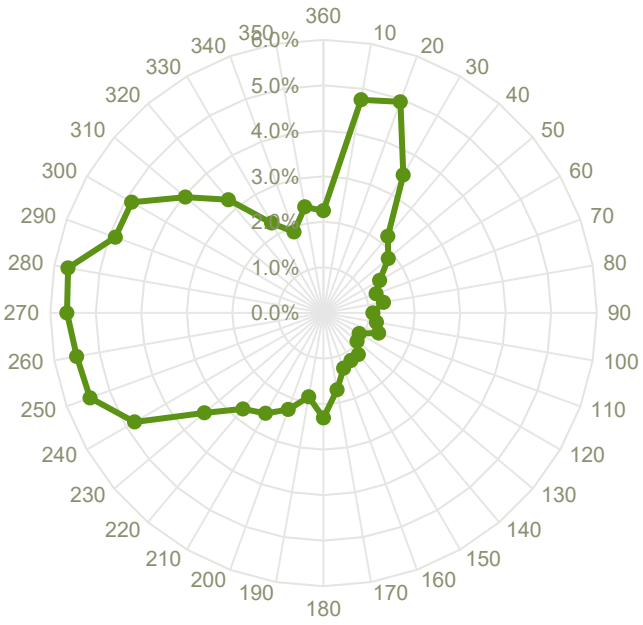


FIGURE 3-47 FREQUENCY DISTRIBUTION OF WINDS DIRECTION WHEN RAINING AT JANDAKOT (2005-PRESENT)

An analysis on the frequency of the wind speeds is presented in the figures below. The analysis has been completed for a raindrop of 1.75mm in diameter. The assessment does not include periods of rainfall where there is no wind. In these instances, the rain will fall vertically (at no angle) and it is assumed that any obstruction above passengers will provide protection from this rainfall. The following figures are representative of the rain at a 1m ground level (i.e. concourse level).

FIGURE 3-48 WEST DIRECTION FREQUENCY DISTRIBUTION (1M GROUND LEVEL)

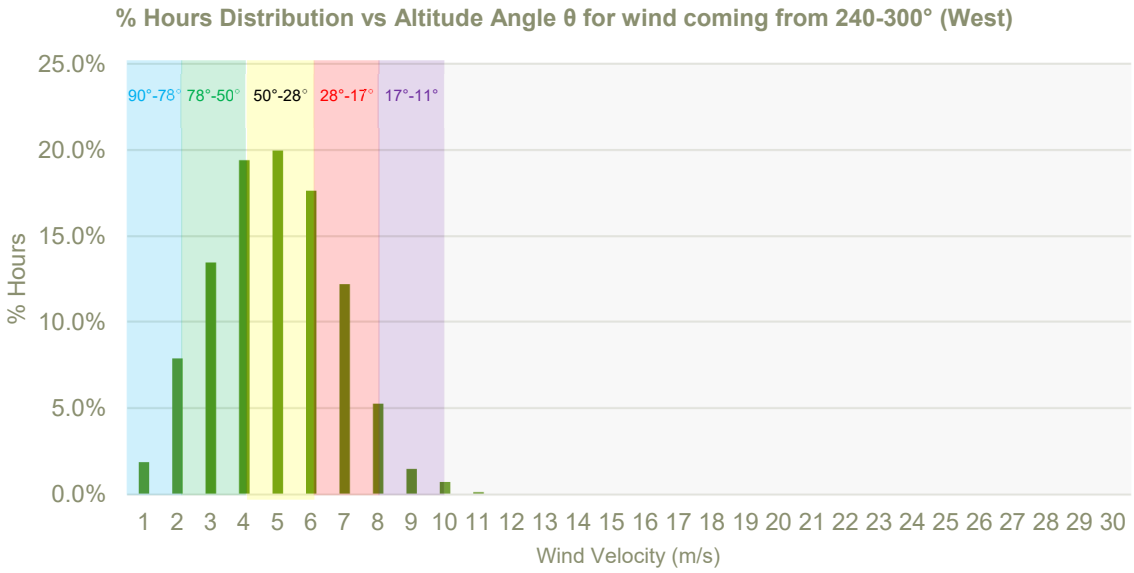


Figure 3-48 shows the following different rain angles and how frequently they occur:

- 0° to 11° - less than 1%
- 11° to 17° (purple) – 2.2%
- 17° to 28° (red) – 17.4%
- 28° to 50° (yellow) – 37.6%
- 50° to 78° (green) – 32.9%
- 78° to 90° (blue) – 9.7%

FIGURE 3-49 NORTH DIRECTION FREQUENCY DISTRIBUTION (1M GROUND LEVEL)

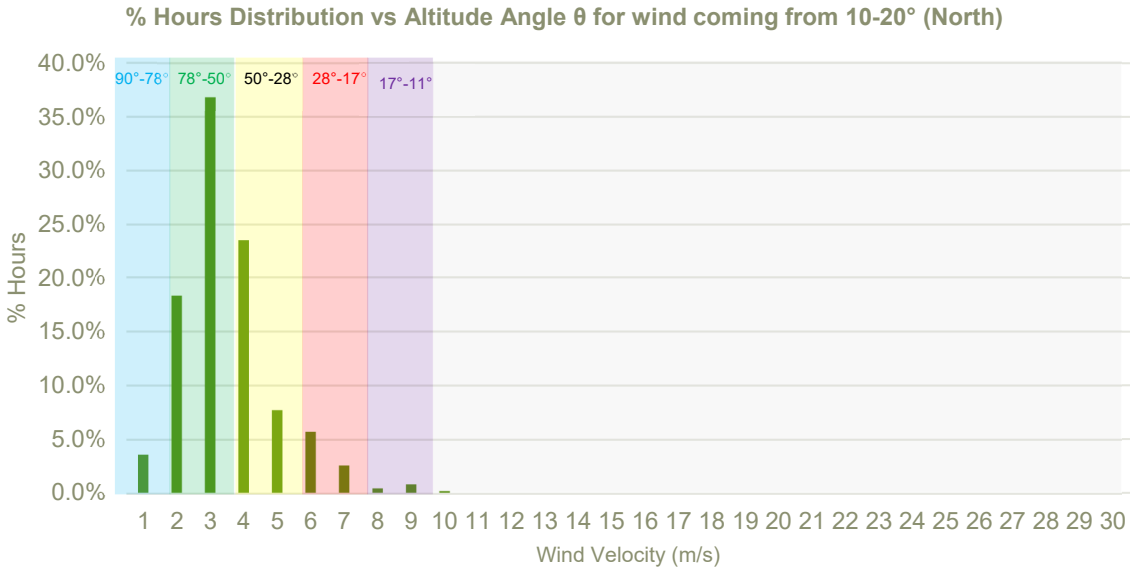


Figure 3-49 shows the following different rain angles and how frequently they occur:

- 0° to 11° - less than 1%
- 11° to 17° (purple) – 1.1%
- 17° to 28° (red) – 3.1%
- 28° to 50° (yellow) – 13.4%
- 50° to 78° (green) – 60.4%

- 78° to 90° (blue) – 21.9%

Perth Metro

In Perth Metro, the mean annual rainfall is 736.8mm and it rains for 6% of the year.

Table 3-17 and Table 3-18 below show the times of year and the time of day when it is likely to rain. The tables indicate:

- The majority (52%) of rainfall occurs in winter
- The time of day at which rainfall occurs is evenly distributed throughout the day

TABLE 3-17 FREQUENCY OF RAINFALL BASED ON SEASON

Period	Months	Occurrence
Summer	Dec - Feb	7%
Autumn	Mar - May	21%
Winter	Jun - Aug	52%
Spring	Sep - Nov	19%

TABLE 3-18 FREQUENCY OF RAINFALL BASED ON TIME

Period	Time	Occurrence
Night	0:00 - 06:00	27%
Morning	06:00 - 12:00	24%
Afternoon	12:00 - 18:00	24%
Evening	18:00 - 24:00	25%

Figure 3-50 below shows that when rain is falling, there is one prevailing wind direction:

- West (220° to 300°) accounting for 49.1% of the annual hours when precipitation occurs

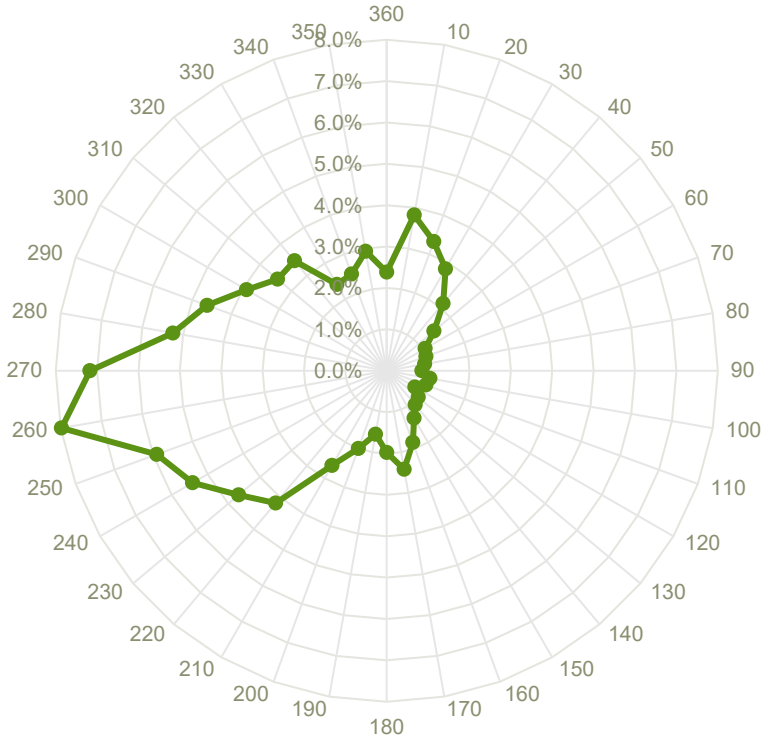


FIGURE 3-50 FREQUENCY DISTRIBUTION OF WINDS DIRECTION WHEN RAINING AT PERTH METRO (2005-PRESENT)

An analysis on the frequency of the wind speeds is presented in the figures below. The analysis has been completed for a raindrop of 1.75mm in diameter. The assessment does not include periods of rainfall where there is no wind. In these instances, the rain will fall vertically (at no angle) and it is assumed that any obstruction above passengers will provide protection from this rainfall. The following figures are representative of the rain at a 1m ground level (i.e. concourse level).

FIGURE 3-51 WEST DIRECTION FREQUENCY DISTRIBUTION (1M GROUND LEVEL)

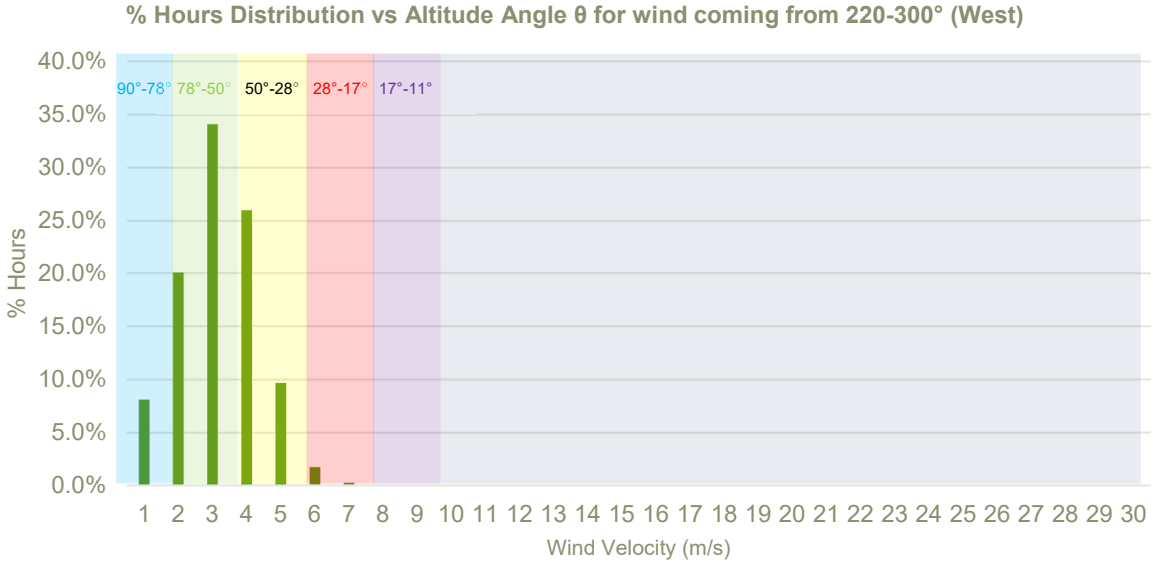


Figure 3-51 shows the following different rain angles and how frequently they occur:

- 0° to 11° - less than 1%
- 11° to 17° (purple) – less than 1%
- 17° to 28° (red) – less than 1%
- 28° to 50° (yellow) – 11.4%

- 50° to 78° (green) – 60.1%
- 78° to 90° (blue) – 28.2%

Wind Analysis

The purpose of the wind analysis is to provide advice on the probable prevailing wind direction and its impact on waiting passengers on the newly proposed platforms. The methodology for this assessment includes assessing the wind direction and analysing whether shelter is provided through the use of structures or landscaping.

The comfort criteria used in the study is the Lawson[4] criteria, based on the probability of exceeding certain mean wind speeds. The criteria are presented in Table 3-19. Wind conditions are unacceptable when the probability of the mean wind speed exceeding the given number is greater than 5%.

TABLE 3-19 THE LAWSON WIND COMFORT CRITERIA

Threshold Wind Speed	Activity
4 m/s	Uncomfortable for passengers who are sitting
6 m/s	Uncomfortable for passengers who are standing or sitting for shorter periods of time
8 m/s	Uncomfortable for passengers who are leisurely walking
10 m/s	Uncomfortable for passengers who are walking quickly and cycling

As a benchmark, Green Star – Railway Stations requires that wind breaks are provided which provide shelter from prevailing winds to at least 10% of the area of each platform through the use of structure or landscaping.

The prevailing wind directions for each of the weather stations analysed are detailed below.

Jandakot

The average wind speed for Jandakot at ground level is approximately 3 m/s. A frequency distribution of the wind speeds is provided in Figure 3-52 below. The frequency distribution shows that approximately 97% of all wind speeds are below 6 m/s, the maximum speed considered comfortable for passengers sitting or standing for a short period of time. There is therefore only a 3% chance of the wind speed exceeding this criteria, resulting in comfortable wind conditions.

[4] Lawson, T. (1978). The Wind Content of the Built Environment. Journal of Wind Engineering and Industrial Aerodynamics, Volume 3, Issues 2-3, 93-105

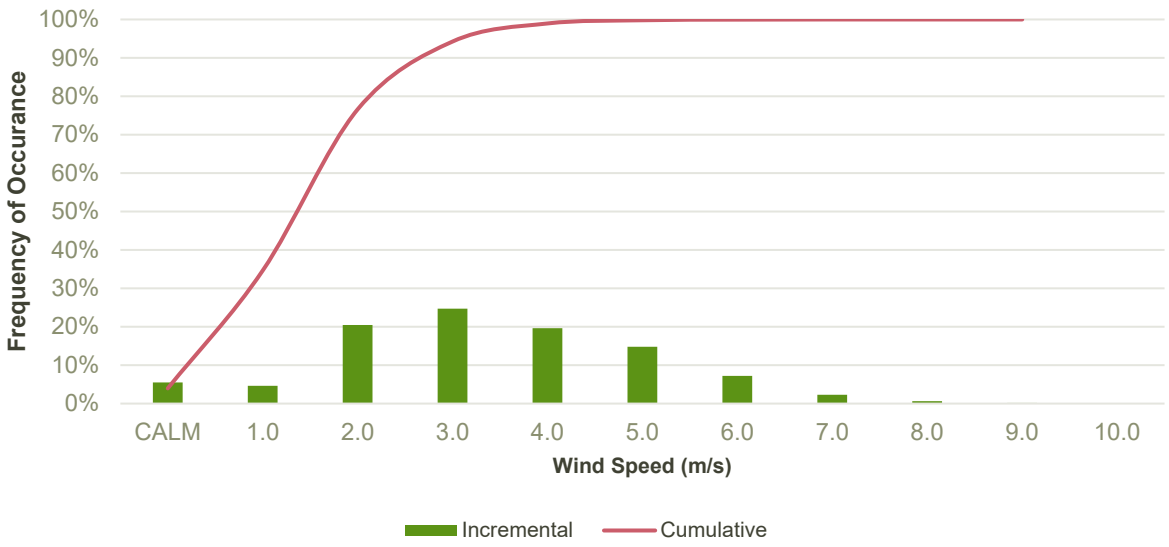


FIGURE 3-52 JANDAKOT WIND SPEED DISTRIBUTION (GROUND LEVEL)

Figure 3-53 demonstrates the wind speed distribution at platform level. At platform level, there is a 24% chance of the wind speed exceeding the Lawson comfort criteria.

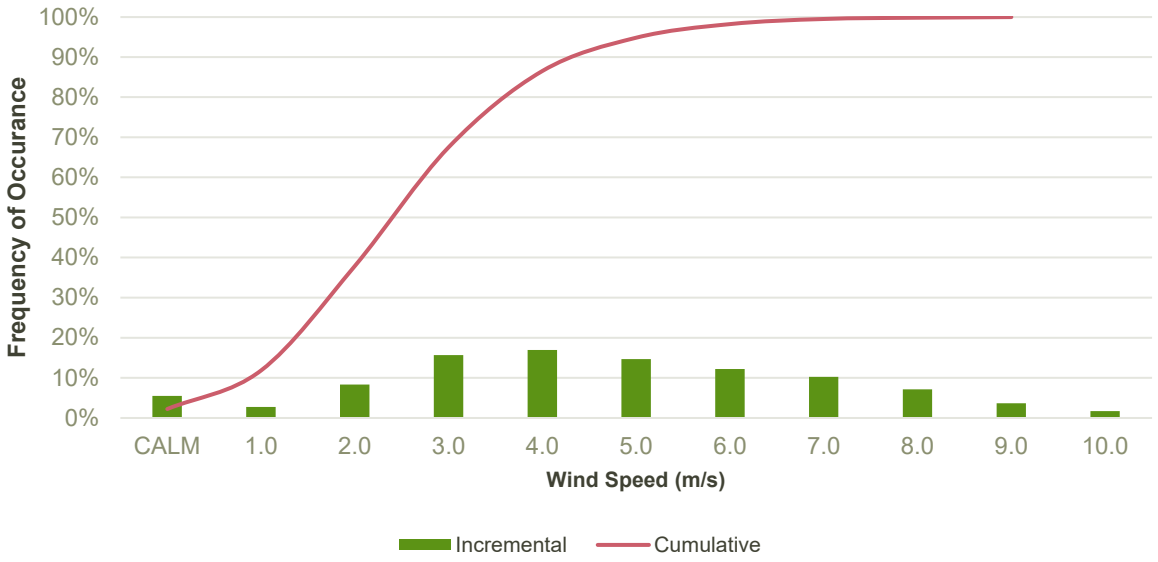


FIGURE 3-53 JANDAKOT WIND SPEED DISTRIBUTION (PLATFORM LEVEL)

To further assess the windspeed and prevailing wind directions, a frequency distribution of the wind direction is provided in Figure 3-54 below.

Figure 3-54 shows that there are three prevailing wind directions:

- East (100° to 110°) accounting for 11.2% of the year
- South (180° to 190°) accounting for 9.6% of the year
- Southwest (220° to 240°) accounting for 12.7% of the year

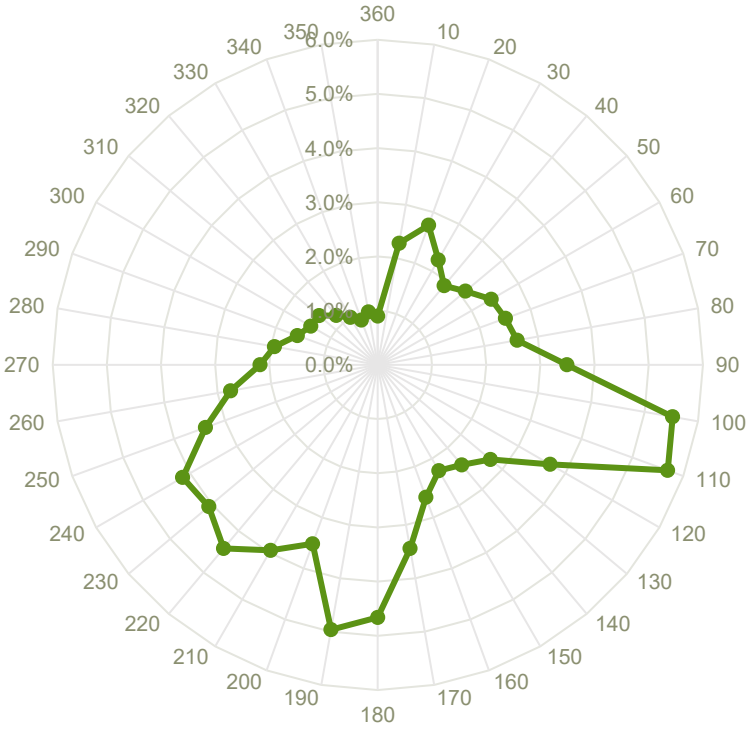


FIGURE 3-54 FREQUENCY DISTRIBUTION OF WINDS DIRECTION AT JANDAKOT (2005-PRESENT)

An analysis on the frequency of the wind speeds, for each of the prevailing wind directions, is presented in the figures below. The assessment only considers periods where there is wind occurring and does not include periods where there is no wind (i.e. calm conditions).

Figure 3-55 below shows the distribution of the wind speeds from the East direction. The figure indicates that most wind speeds fall below 6m/s at the ground level and therefore are likely to be comfortable for passengers who are standing or sitting for short periods of time. When wind is occurring at the ground level, the speed is greater than 6m/s only 2.5% of the time. At the platform level a greater frequency of wind has a speed of 6m/s or above. Approximately 46.1% of time when wind is occurring a speed of 6m/s is exceeded.

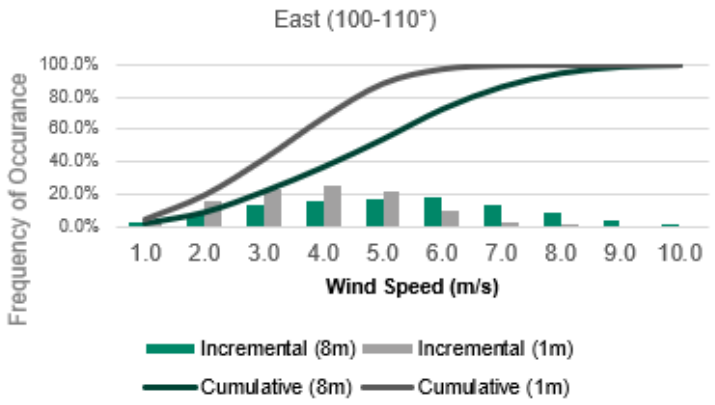


FIGURE 3-55 DISTRIBUTION OF EAST WIND SPEEDS (110 – 110°)

Figure 3-56 below shows the distribution of the wind speeds from the South direction. The figure indicates that at ground level most wind speeds fall below 6m/s and therefore are likely to be comfortable for passengers who are standing or sitting for short periods of time. When wind is occurring at ground level, the speed is greater than 6m/s less than 0.5% of the time. At platform level when wind is occurring, speeds exceed 6m/s for approximately 12.4% of the time.

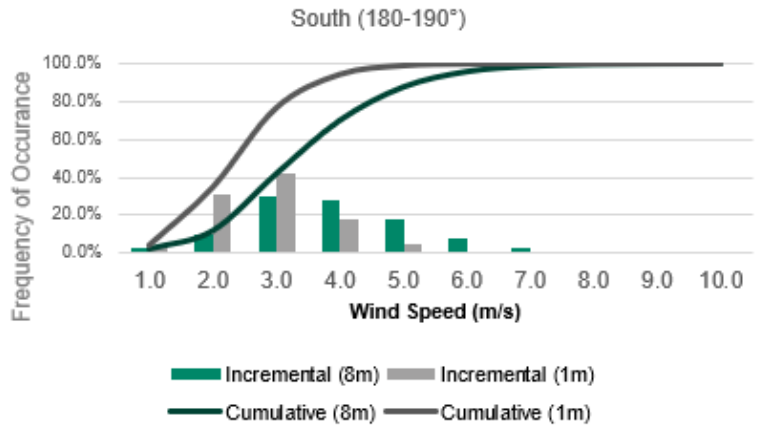


FIGURE 3-56 DISTRIBUTION OF SOUTH WIND SPEEDS (180-190°)

Figure 3-57 below shows the distribution of the wind speeds from the Southwest direction. The figure indicates that at ground level most wind speeds fall below 6m/s and therefore are likely to be comfortable for passengers who are standing or sitting for short periods of time. When wind is occurring at ground level, the speed is greater than 6m/s only 5% of the time. At the platform level a greater frequency of wind has a speed of 6m/s or above. Approximately 59.7% of time when wind is occurring a speed of 6m/s is exceeded.

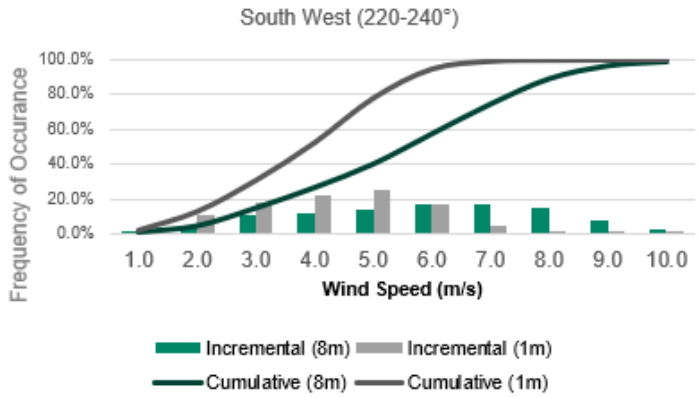


FIGURE 3-57 DISTRIBUTION OF SOUTHWEST WIND SPEEDS (220-240°)

For each of the East, South and Southwest winds, the wind speeds meet the comfort criteria for passengers sitting or standing for short periods of time at ground level. At platform level the comfort criteria is exceeded.

Perth Metro

The average wind speed for Perth Metro at ground level is approximately 2 m/s. A frequency distribution of the wind speeds is provided in Figure 3-58 below. The frequency distribution shows that just under 100% of all wind speeds are below 6 m/s, the maximum speed considered comfortable for passengers sitting or standing for a short period of time. Therefore, resulting in comfortable wind conditions.

FIGURE 3-58 PERTH METRO WIND SPEED DISTRIBUTION (GROUND LEVEL)

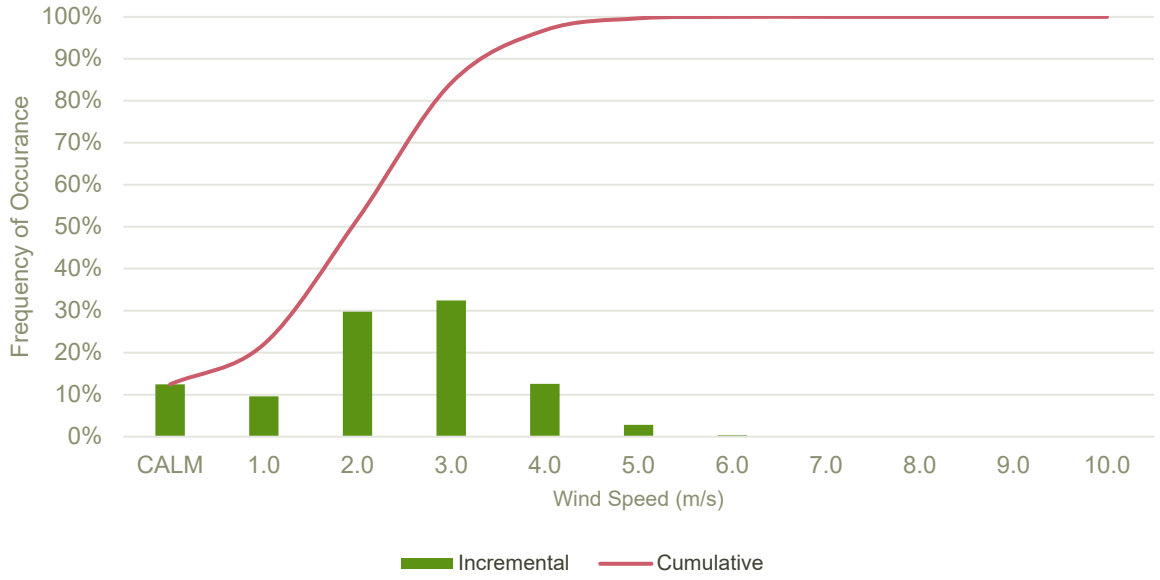


Figure 3-59 demonstrates the wind speed distribution at platform level. At platform level, there is a 9% chance of the wind speed exceeding the Lawson comfort criteria.

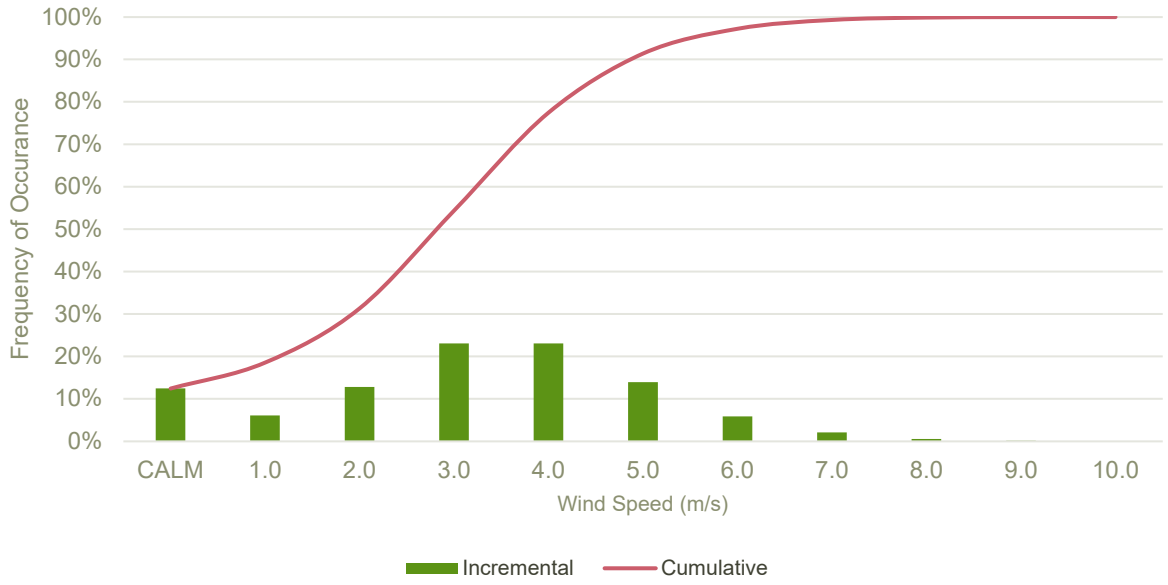


FIGURE 3-59 PERTH METRO WIND SPEED DISTRIBUTION (PLATFORM LEVEL)

To further assess the windspeed and prevailing wind directions, a frequency distribution of the wind direction is provided in Figure 3-60 below.

Figure 3-60 shows that there are three prevailing wind directions:

- Southwest (210° to 220°) accounting for 12.7% of the year
- South (170°) accounting for 5.8% of the year
- East (90° to 100°) accounting for 8.7% of the year

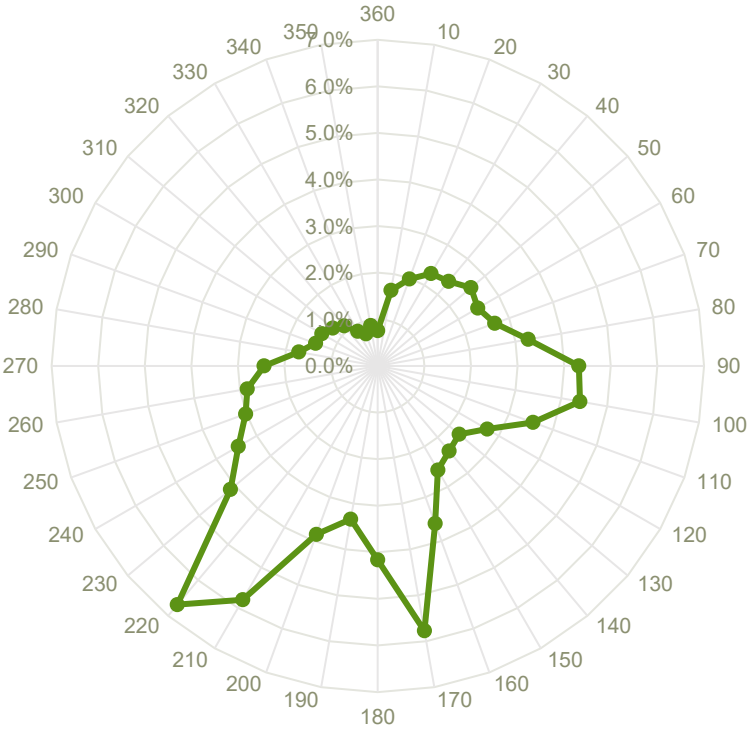


FIGURE 3-60 FREQUENCY DISTRIBUTION OF WINDS DIRECTION AT PERTH METRO (2005-PRESENT)

An analysis on the frequency of the wind speeds, for each of the prevailing wind directions, is presented in the figures below. The assessments only consider periods where there is wind occurring and does not include periods where there is no wind (i.e. calm conditions).

Figure 3-61 below shows the distribution of the wind speeds from the Southwest direction. The figure indicates that most wind speeds at ground level fall below 6m/s and therefore are likely to be comfortable for passengers who are standing or sitting for short periods of time. When wind is occurring at ground level, the speed is greater than 6m/s only 2% of the time. At platform level, the speed is greater than 6m/s 32% of the time.

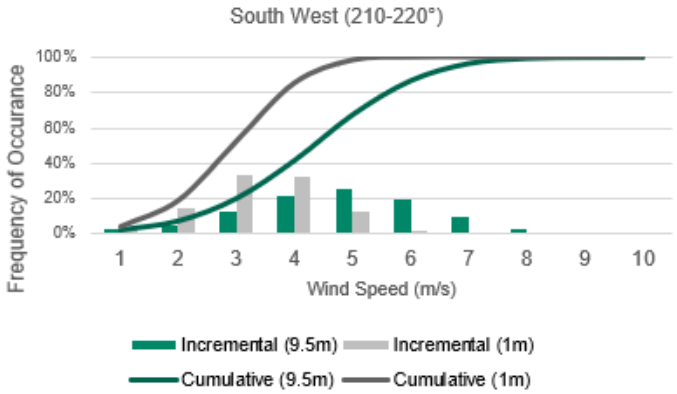


FIGURE 3-61 DISTRIBUTION OF SOUTHWEST WIND SPEEDS (210-220°)

Figure 3-62 below shows the distribution of the wind speeds from the South direction. The figure indicates that all wind speeds at ground level fall below 6m/s and therefore are likely to be comfortable for passengers who are standing or sitting for short periods of time. At platform level, when wind is occurring a speed of 6m/s is exceed only 0.2% of the time.

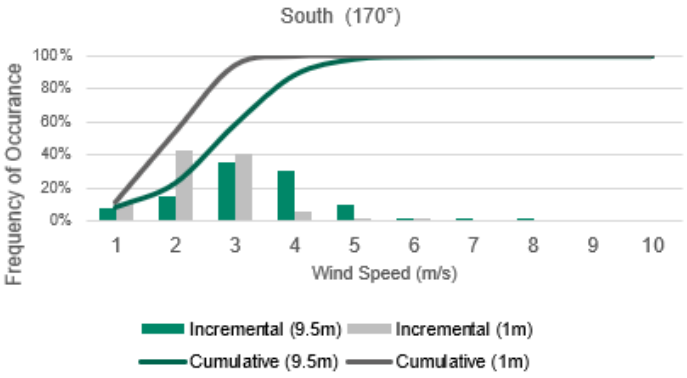


FIGURE 3-62 DISTRIBUTION OF SOUTH WIND SPEEDS (170°)

Figure 3-63 below shows the distribution of the wind speeds from the East direction. The figure indicates that at ground level all wind speeds fall below 6m/s and therefore are likely to be comfortable for passengers who are standing or sitting for short periods of time. At platform level, when wind is occurring speeds exceed 6m/s 0.2% of the time.

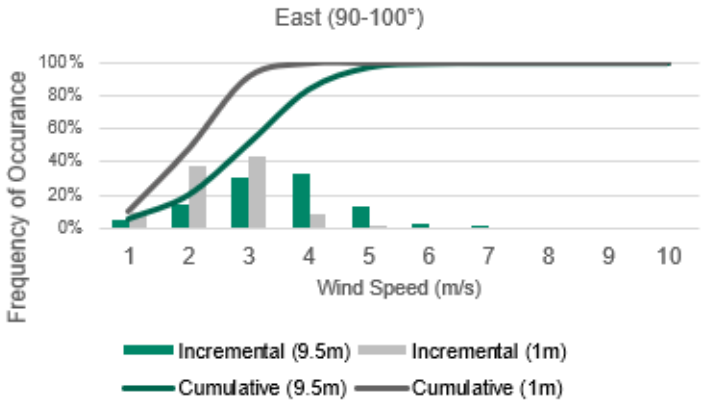
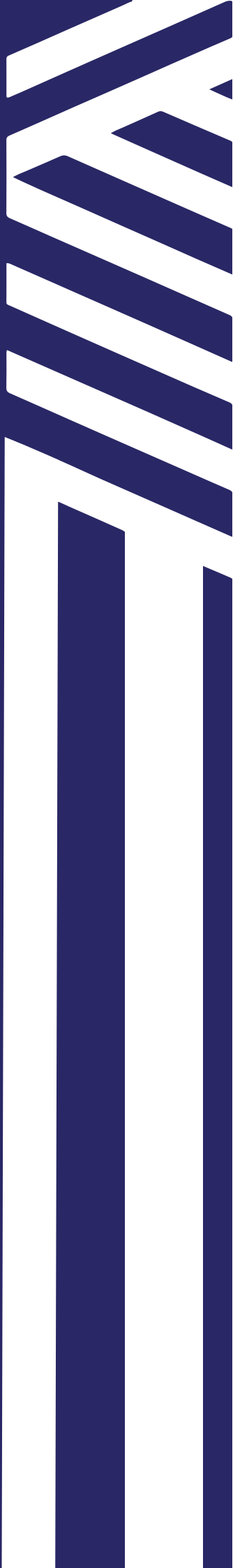


FIGURE 3-63 DISTRIBUTION OF EAST WIND SPEEDS (90-100°)

For each of the Southwest, South and East winds, the wind speeds meet the comfort criteria for passengers sitting or standing for short periods of time.



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