Appendix T – Environmental Comfort Assessment – Queens Park Station prepared by ALUA

VICTORIA PARK TO CANNING

LEVEL CROSSING REMOVAL PROGRAM

PTA 200140

ENVIRONMENTAL COMFORT ASSESSMENT QUEENS PARK 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
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 Queens Park 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 has now been updated to reflect the FDD. An additional assessment has also been completed to assess the wind comfort at the station entrance.

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 the Green Star – Design & As Built v1.2 tool and has been prepared for use on the above-ground and underground railway stations.

The information provided in the following report and previous assessments have 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 Queens Park 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 ITEMS 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 the provision of additional screening to mitigate the 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 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		

#	Scope Item	Applicable Areas / Studies
22.4.5-3-18	Wind study demonstrating that the design of station 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 PTA minutes in the appendix.	Solar access and control Wind Rain Protection Solar Reflection Natural lighting
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 a detailed assessment of 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 NOA 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 for each platform. Up Main: • At 2pm, for areas not enclosed by the metal sheeting on the canopy shell, some solar exposure will occur, particularly during spring and autumn. Areas enclosed by the metal sheeting on the canopy shell will be protected from the summer sun. The 20% shaded target for Green Star is likely to be met at this time for the summer sun only. • At 6pm, due to the low altitude of the sun, there will be full solar for areas not enclosed by the metal sheeting on the canopy shell. Areas enclosed by the metal

Scope Item	Comments
	sheeting on the canopy shell will be protected. The 20% shaded target for Green Star is likely to be met at this time. Down Main: • At 2pm, the platform will receive solar exposure with some limited protection towards the back of the platform. Within the platform areas enclosed in the metal sheeting-protected canopy shell, the protected area increases due to the increased depth of the platform. The 20% shaded target for Green Star is unlikely to be met at this time. • At 6pm, due to the low altitude of the sun, there will be full solar exposure on the platform. The 20% shaded target for Green Star is unlikely to be met at this time. • Note that while the Down Main platform does not meet the Green Star percentage target, typically passengers commuting on this platform will be arriving at the platform (i.e., returning from the CBD) and not waiting at the platform for an extended period.

Solar Reflection

The sun path for Perth was used to determine any areas prone to the 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 a detailed assessment of solar reflection, refer to section 3.2.

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 NOA and will be covered by the mechanical engineering design team. A solar reflection environmental assessment has been completed which identified 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 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. Refer to previous NOA and desktop studies for potential design solutions.

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 a detailed assessment of 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 in 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 meeting minutes in the appendix.

TABLE 0-4 – RAIN PROTECTION SCOPE ITEMS

Scope Item	Comments
22.1-19	*Platform Roofing: The NOP shall review the provision of additional screening to mitigate the 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, the prevailing wind directions are North and West. The Western and Northern rain angle environmental assessments have been completed in section 3.3.3 below which identified the following: **Platform safe zones:** The rain from the West is unlikely to affect the Up Main Platform Safe Zone but could penetrate the full depth of the Down Main Platform Safe Zone depending on the rainfall angle. The most common occurring Western rainfall angles (which impact the safe zones) will occur for less than approximately 3.6% of the time annually. The rain from the North is unlikely to affect the Down Main Platform Safe Zone but could penetrate the full depth of the Up Main Platform Safe Zone depending on the rainfall angle. The most common occurring Northern rainfall angles (which impacts the safe zones) will occur for less than approximately 5.1% of the time annually. **Lift zones:** The rain from the West is unlikely to affect the Up Main Platform Northern and Southern Lift Zones. However, the Western rain could potentially penetrate under the edge of the Down Main canopy shell. This could impact both the Northern and Southern Lift Entry Zones. The most common occurring Western rainfall angles (which impact the lift zones) will occur for less than approximately 3.6% of the time annually. The rain from the North is unlikely to affect the Down Main Platform. However, the Northern rain could potentially penetrate under the edge of the Up Main Platform canopy. This could impact both the Up Main Platform Northern and Southern Lift Entry Zones. The most common occurring Northern rainfall angles (which impact the lift zones) occur for less than approximately 5.1% of the time annually. **Pedestrian stairs area:** It is expected that the perforated screen in the canopy shell will provide some protection to the Up Main Platform stairs from Western rain but will not completely prevent rain from entering. However, note that historic data indicates it rains for 7% of the year. The Western rain could enter the full depth of the pedestrian stairs on the Down Main Platform depending on the rainfall angle. The most common occurring Western rainfall angles (which impact the pedestrian stairs) will occur for less than approximately 3.6% of the time annually. It is expected the perforated screen in the canopy shell will provide some protection to the Down Main Platform stairs from Northern rain but will not completely prevent rain from entering. However, note that historic data indicates it rains for 7% of the year. The Northern rain could enter the full depth of the pedestrian stairs on the Up Main Platform Stairs depending on the rainfall angle. The most common occurring Northern

Scope Item	Comments
	rainfall angles (which impact the pedestrian stairs) occur less than approximately 5.1% of the time annually. **Station Entry and Foyer:** The Western and Northern rain is unlikely to impact the concourse floor just before the station entrance.
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.
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.* As indicated in the rain comfort assessment, due to the orientation of the rail corridor, the prevailing rain angles have the potential to penetrate under the canopy during periods of faster wind speeds, regardless of the length of the canopy cover (i.e., due to the most frequent rainfall falling at an angle of 17° to 50° from the West and 28° to 78° degrees from the North underneath the canopy). A longer canopy will protect passengers from rain falling vertically, however it is not anticipated that a longer canopy will provide significant additional protection for the southernmost lift on each platform from wind driven rain, due to the angle at which the most common rainfall occurs. Note that it rains for approximately 7% of the year based on past weather data and therefore the times of year that the exposed platform is impacted, or that rain could penetrate under the canopy is minimal.

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 are 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 a detailed assessment of wind protection, refer to section 3.4.

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 station 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, as per Green Star v1.1 requirements, at least 10% of the platform area is protected from prevailing winds due to the canopy shell.
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 and metal screening adjacent to the lifts, there is protection from the prevailing winds at each lift entry. An extended canopy is not expected to provide

[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

Scope Item	Comments
	additional protection from the wind without a vertical element to the canopy, as the passengers would be exposed to wind underneath the canopy.

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 has now been updated to reflect the FDD design.

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 the 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 have 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-QP-SN-AR-M3D-00001.rvt	Accessed week of 9/1/2023
BIM 360 2D Drawings	Station Wide Axonometric (04-A-72-AR0156) Site Plan (04-A-72-AR0160) GA Plans (04-A-72-AR0161) GA Elevations (04-A-72-AR0164) GA Cross Sections (04-A-72-AR0199 to AR0203) GA Long Sections (04-A-72-AR0195 to AR0198) Concourse Plan (04-A-72-AR0167 to AR0169) Platform Plan (04-A-72-AR0170 to AR0172) Elevations (04-A-72-AR0186 to AR0194)	Accessed week of 9/1/2023

2. Station Details

2.1 Location and Weather

Historic weather data from the Jandakot weather station was obtained from the Bureau of Meteorology for analysis. Jandakot is the closest weather station to Queens Park Station, located approximately 11km to the Southwest. Refer to Appendix **Error! Reference source not found.** 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 Queens Park 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. The Queens Park Station is located in the Southern and South-Western Flatlands West sub-cluster.

Climate change projections for the Queens Park Station location indicate that average 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 Queens Park 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
- New concourse
- New utilities
- New amenities

Figure 2-1 to Figure 2-5 shows 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 Hamilton and Wharf Streets' level crossings.

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.

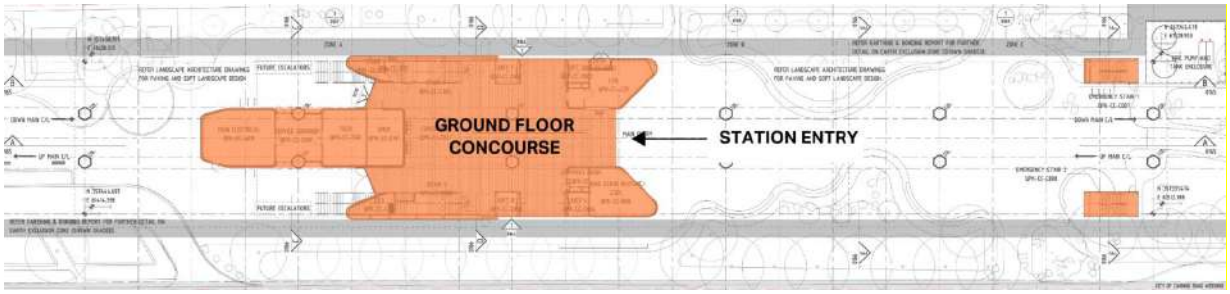

FIGURE 2-2 PROPOSED WORKS (GROUND FLOOR CONCOURSE)

Figure 2-3 below indicates the new Up Main platform and Down Main platform.

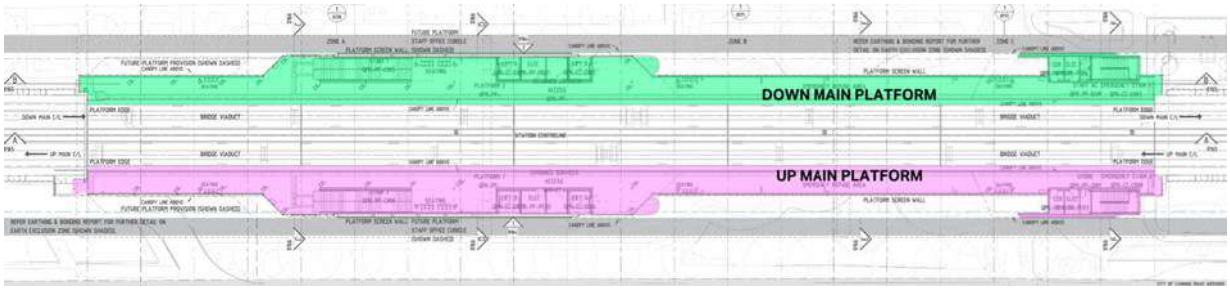

FIGURE 2-3 PROPOSED WORKS (PLATFORMS)

As illustrated in Figure 2-4 and Figure 2-5 below, the weather screen with a height of approximately 1.76m (from platform level), runs along the boundary on both platforms. Additionally, a canopy shell comprising metal sheeting, perforated screen, transparent screen, and cladding is used to protect certain areas of the platforms.

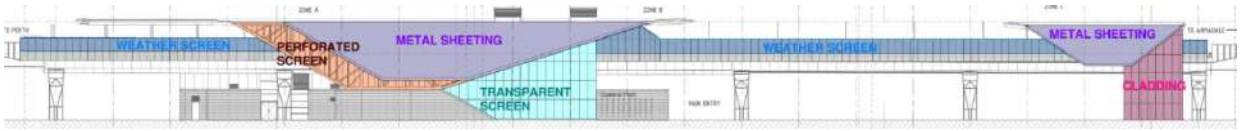

FIGURE 2-4 PROPOSED WEATHER SCREEN, PERFORATED SCREEN, METAL SHEETING AND TRANSPARENT SCREEN (WEST ELEVATION)

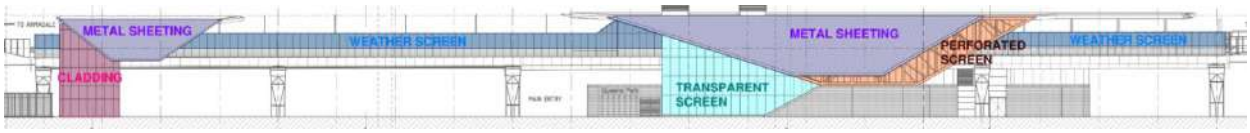

FIGURE 2-5 PROPOSED WEATHER SCREEN, PERFORATED SCREEN, METAL SHEETING AND TRANSPARENT SCREEN (EAST ELEVATION)

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:

- Updating the screening in the canopy shell from louvres to perforated metal
- Slight changes to the canopy height and length (Reference Design included a staggered canopy height)

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 Queens Park Station includes several items relating to environmental comfort. These are identified in **Error! Reference source not found.** below.

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

TABLE 2-1 – SWTC SCOPE ITEMS AND PTA SPECIFICATION ITEM

#	Scope Item	Applicable Areas / Studies
22.1 Station Precinct, Station Buildings and Facilities General Requirements		
22.1-19	Platform Roofing: The NOP shall review the provision of additional screening to mitigate the 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 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 station 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 PTA minutes in the appendix.	Solar access and control Wind Rain Protection Solar Reflection Natural lighting
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 Queens Park Station Platforms. Consequently, the environmental assessment is conducted on various locations of both platforms as shown in Figure 2-6. These locations include typical platform areas, pedestrian stairs areas, platform safe zones and lift zones.

It is assumed that the architectural canopy shell with metal sheeting provides full protection from solar exposure, wind, and rain. The solid, transparent screen/glazing is assumed to provide full protection from rain and wind however limited protection from solar exposure. The perforated screen is assumed to provide some protection from solar exposure, wind and rain, however, will not fully restrict rain from entering.

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

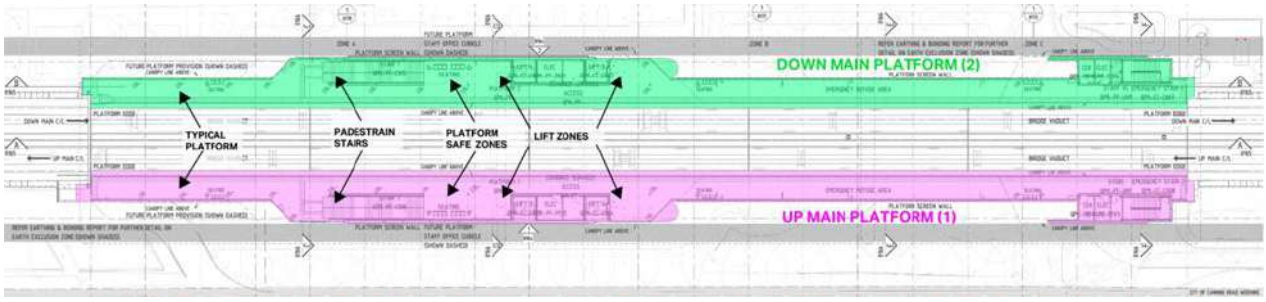

FIGURE 2-6 PLATFORM ASSESSMENT AREAS

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 prevent prevailing weather from affecting 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.

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 the 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 ensure 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 NOA 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 for each platform. Up Main: • At 2pm, for areas not enclosed by the metal screen on the canopy shell, some solar exposure will occur, particularly during spring and autumn. Areas enclosed by the metal screen on the canopy shell will be protected from the summer sun. The 20% shaded target for Green Star is likely to be met at this time for the summer sun only. • At 6pm, due to the low altitude of the sun, there will be full solar for areas not enclosed by the metal screen on the canopy shell. Areas enclosed by the metal screen on the canopy shell will be protected. The 20% shaded target for Green Star is likely to be met at this time. Down Main: • At 2pm, the platform will receive solar exposure with some limited protection towards the back of the platform. Within the platform areas enclosed in the metal screen-protected canopy shell, the protected area increases due to the increased depth of the platform. The 20% shaded target for Green Star is unlikely to be met at this time. • At 6pm, due to the low altitude of the sun, there will be full solar exposure on the platform. The 20% shaded target for Green Star is unlikely to be met at this time. • Note that while the Down Main platform does not meet the Green Star percentage target, typically passengers commuting on this platform will be arriving at the platform (i.e., returning from the CBD) and not waiting at the platform for an extended period.

3.1.2 Assessment Results

Platform areas that are enclosed by the metal sheeting (without a transparent or perforated screen) on the Up Main Platform are completely shaded between 2 pm and 6 pm.

Figure 3-1 and Figure 3-2 below indicate that the Up Main Platform (where it is protected only by the perforated weather screen and platform canopy) will be partially shaded from the 2pm sun, however, will likely see 6pm solar exposure penetrates under the canopy. This is indicated in the figures below as red (summer solstice), orange (autumn equinox) and yellow (spring equinox).

Similarly, the Down Main Platform will have some limited platform area shaded at 2pm, however, the 6pm solar exposure will likely penetrate under the canopy.

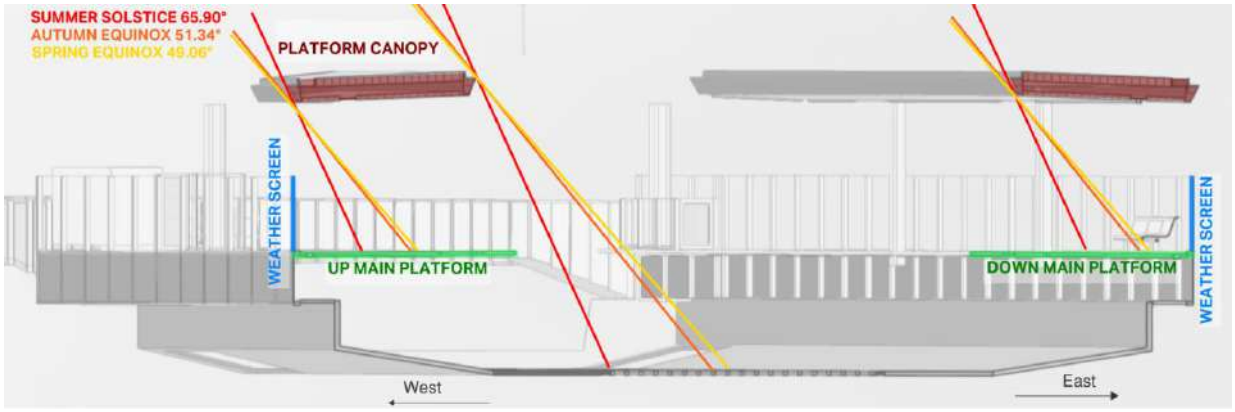

FIGURE 3-1 SUN ALTITUDE 2PM (TYPICAL PLATFORM AREA)

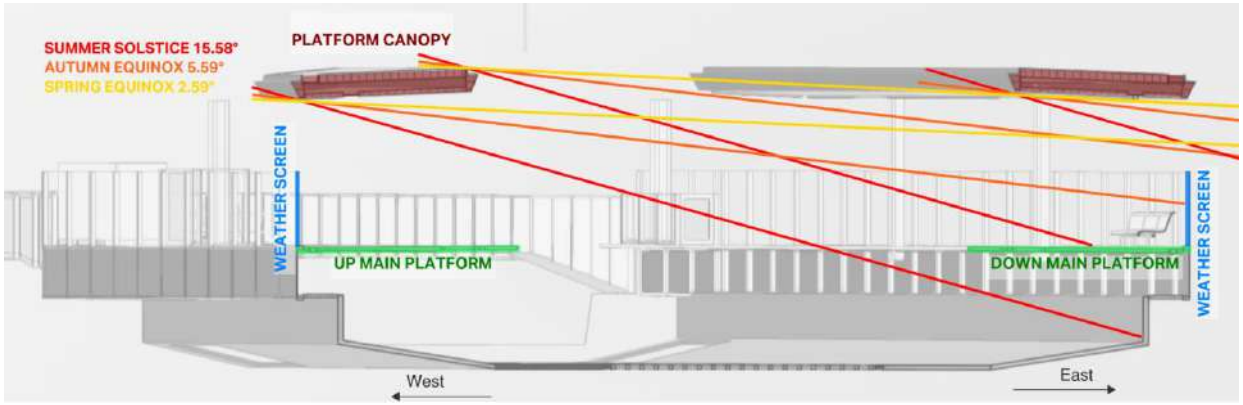

FIGURE 3-2 SUN ALTITUDE 6PM (SECTION)

Figure 3-3 and Figure 3-4 show the azimuth angle (the compass direction from which the sunlight is coming) on the Up Main and Down Main Platforms.

The figures demonstrate that when the azimuth angle is taken into consideration, at 2pm, both platforms are relatively exposed to the autumn and spring sun (highlighted in yellow). However, the Up Main platform is protected from the summer sun (highlighted in orange) due to the metal sheeting in the canopy shell.

At 6pm, the Up Main platform is well protected from the summer, autumn and spring suns due to the metal sheeting in the canopy shell. The Down Main platform is exposed to sunlight during summer, autumn and spring.

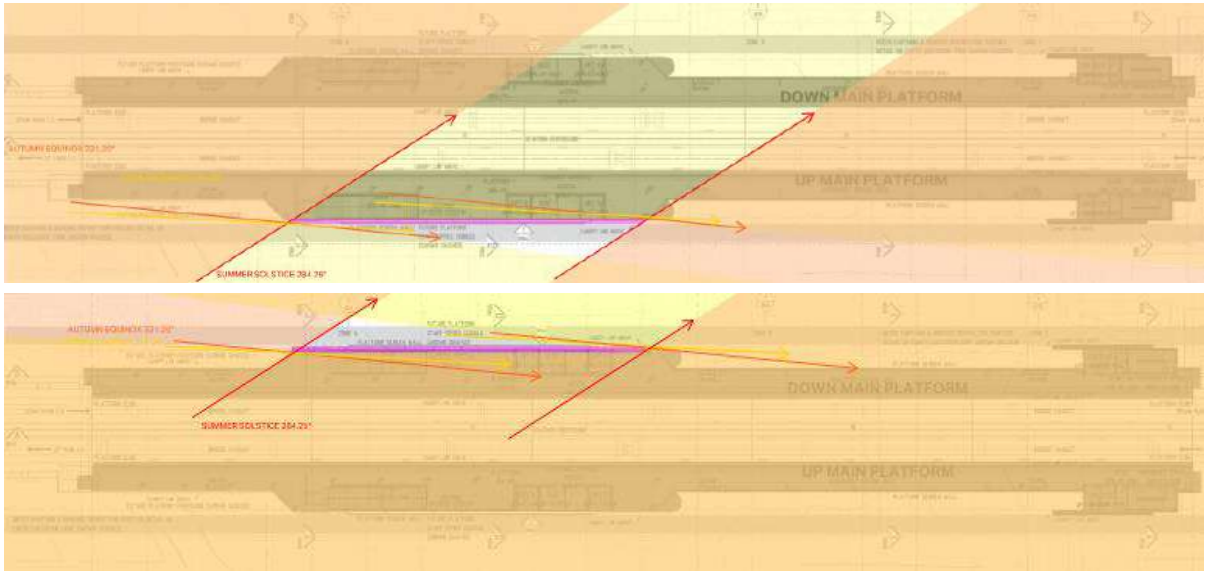

FIGURE 3-3 SUN AZIMUTH ANGLE 2PM (PLAN) - UP MAIN PLATFORM (TOP) DOWN MAIN PLATFORM (BOTTOM)

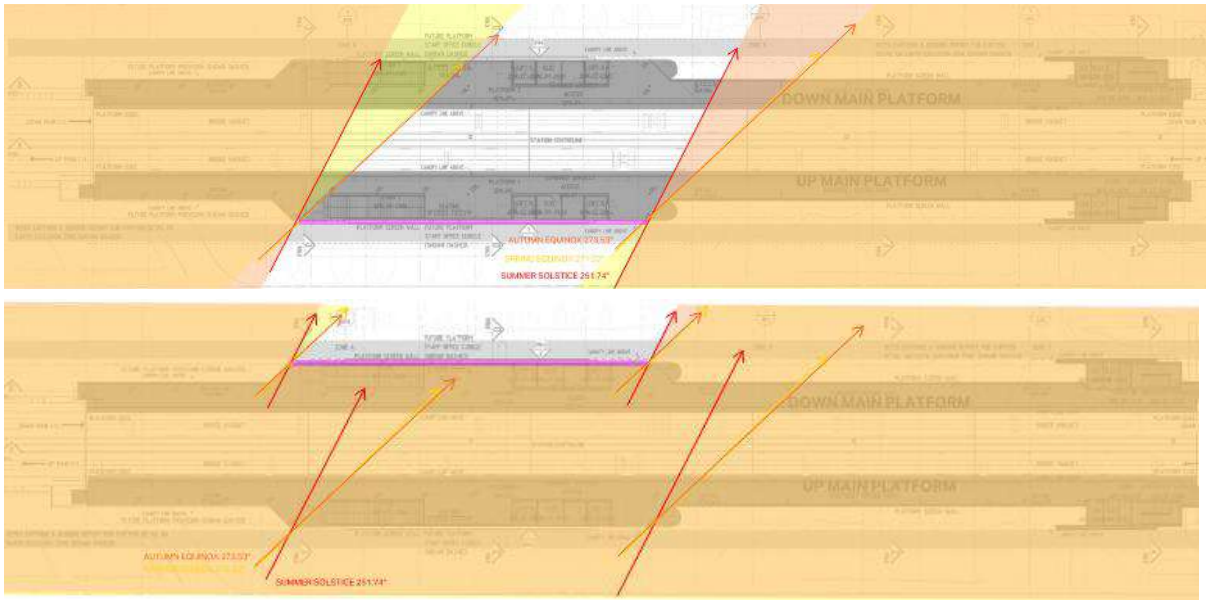

FIGURE 3-4 SUN AZIMUTH ANGLE 6PM (PLAN) -UP MAIN PLATFORM (TOP) DOWN MAIN PLATFORM (BOTTOM)

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 new infrastructure in the development. 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 NOA 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 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 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. Refer to previous NOA and desktop studies for potential design solutions.

3.2.2 Assessment Results

Figure 3-5 below shows the sun's 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, as indicated in yellow in the figure. The directions where the sun is shining are indicated by the angles on the circumference of 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 the blue line denote the paths of the sun when travelling across the June (winter) solstice and December (summer) solstice, respectively. Refer to Appendix **Error! Reference source not found.** for additional details on the sun path diagram.

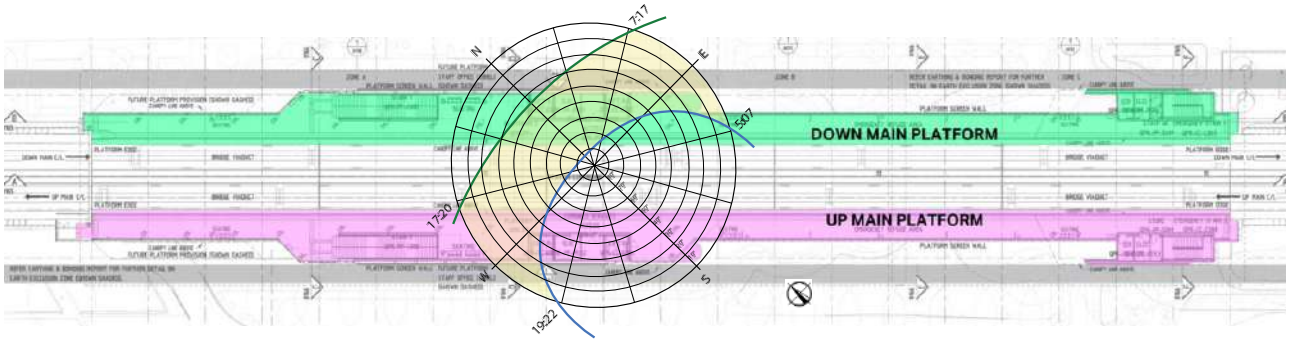

FIGURE 3-5 SUN PATH DIAGRAM

3.3 Rain Protection

The aim of this analysis is to provide advice on probable rainfall and its impact on waiting for 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 refer to stations where morning and afternoon commuting passengers regularly fill the platform.

However, 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 meeting minutes in the appendix.

Historical rain and wind data obtained from the Bureau of Meteorology was used to determine the prevailing wind direction and rain angle. For Queens Park 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°) accounts for 36.8% of the annual hours when precipitation occurs
- North (10° to 20°) accounts for 9.7% of the annual hours when precipitation occurs

The wind speed in these directions was 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 3-6 and Figure 3-7 below.

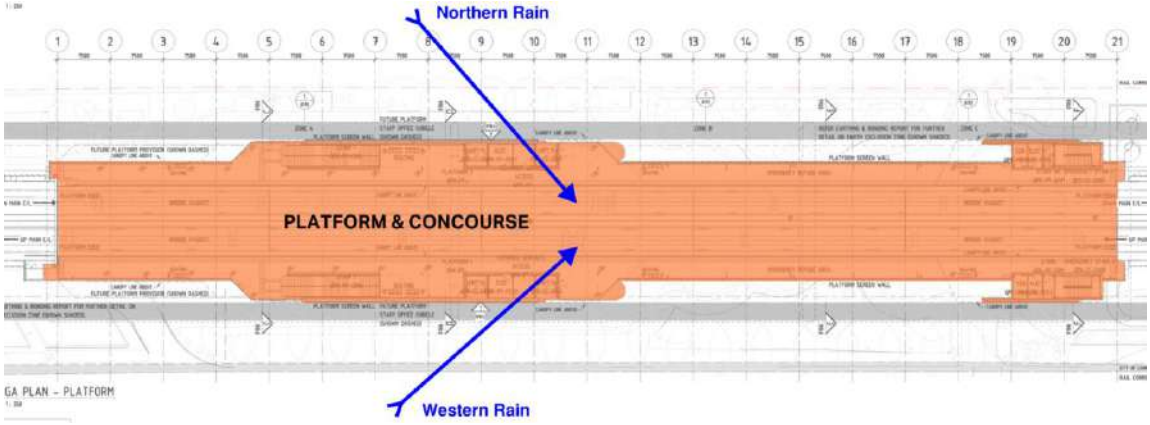

FIGURE 3-6 PLAN

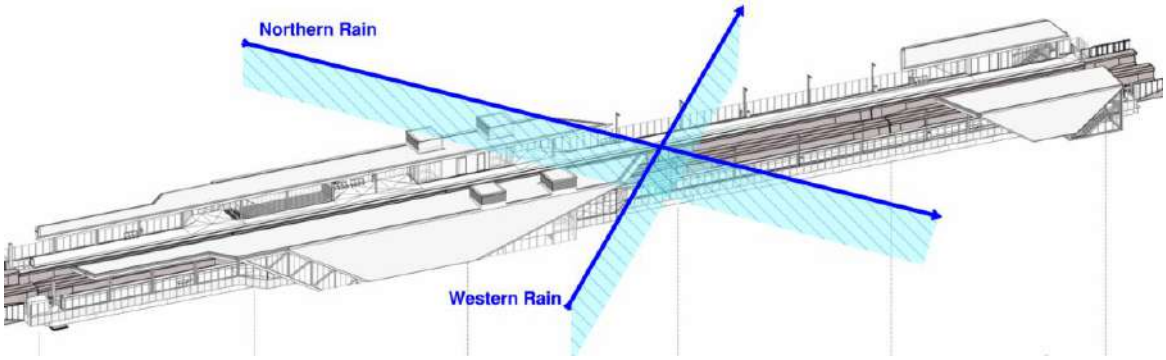

FIGURE 3-7 AXONOMETRIC (VISUAL REPRESENTATION)

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 8 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 8 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 the provision of additional screening to mitigate the 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
	The Western and Northern rain angle environmental assessments have been completed in section 3.3.3 below which identified the following: **Platform safe zones:** The rain from the West is unlikely to affect the Up Main Platform Safe Zone but could penetrate the full depth of the Down Main Platform Safe Zone depending on the rainfall angle. The most common occurring Western rainfall angles (which impact the safe zones) will occur for less than approximately 3.6% of the time annually. The rain from the North is unlikely to affect the Down Main Platform Safe Zone but could penetrate the full depth of the Up Main Platform Safe Zone depending on the rainfall angle. The most common occurring Northern rainfall angles (which impacts the safe zones) will occur for less than approximately 5.1% of the time annually. **Lift zones:** The rain from the West is unlikely to affect the Up Main Platform Northern and Southern Lift Zones. However, the Western rain could potentially penetrate under the edge of the Down Main canopy shell. This could impact both the Northern and Southern Lift Entry Zones. The most common occurring Western rainfall angles (which impact the lift zones) will occur for less than approximately 3.6% of the time annually. The rain from the North is unlikely to affect the Down Main Platform. However, the Northern rain could potentially penetrate under the edge of the Up Main Platform canopy. This could impact both the Up Main Platform Northern and Southern Lift Entry Zones. The most common occurring Northern rainfall angles (which impact the lift zones) occur for less than approximately 5.1% of the time annually. **Pedestrian stairs area:** It is expected that the perforated screen in the canopy shell will provide some protection to the Up Main Platform stairs from Western rain but will not completely prevent rain from entering. However, note that historic data indicates it rains for 7% of the year. The Western rain could enter the full depth of the pedestrian stairs on the Down Main Platform depending on the rainfall angle. The most common occurring Western rainfall angles (which impact the pedestrian stairs) will occur for less than approximately 3.6% of the time annually. It is expected the perforated screen in the canopy shell will provide some protection to the Down Main Platform stairs from Northern rain but will not completely prevent rain from entering. However, note that historic data indicates it rains for 7% of the year. The Northern rain could enter the full depth of the pedestrian stairs on the Up Main Platform Stairs depending on the rainfall angle. The most common occurring Northern rainfall angles (which impact the pedestrian stairs) occur less than approximately 5.1% of the time annually. **Station Entry and Foyer:** The Western and Northern rain is unlikely to impact the concourse floor just before the station entrance.
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.

Scope Item	Comments
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.
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.* As indicated in the rain comfort assessment, due to the orientation of the rail corridor, the prevailing rain angles have the potential to penetrate under the canopy during periods of faster wind speeds, regardless of the length of the canopy cover (i.e., due to the most frequent rainfall falling at an angle of 17° to 50° from the West and 28° to 78° degrees from the North underneath the canopy). A longer canopy will protect passengers from rain falling vertically, however it is not anticipated that a longer canopy will provide significant additional protection for the southernmost lift on each platform from wind driven rain, due to the angle at which the most common rainfall occurs. Note that it rains for approximately 7% of the year based on past weather data and therefore the times of year that the exposed platform is impacted, or that rain could penetrate under the canopy is minimal.

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:

- Platform safe zones (Section 3.3.3.1)
- Lift zones (Section 3.3.3.2)
- Pedestrian stairs area (Section 3.3.3.3)
- Station Entry and Foyer (Section 3.3.3.4)

3.3.3.1 Platform Safe Zone

Western Rain

Figure 3-8 below shows how Western rain may interact with the proposed canopy and canopy shell that wraps around the portion of the Up Main platform above the concourse. Based on the diagram, the rain from the West is not expected to affect the Up Main Platform Safe Zone.

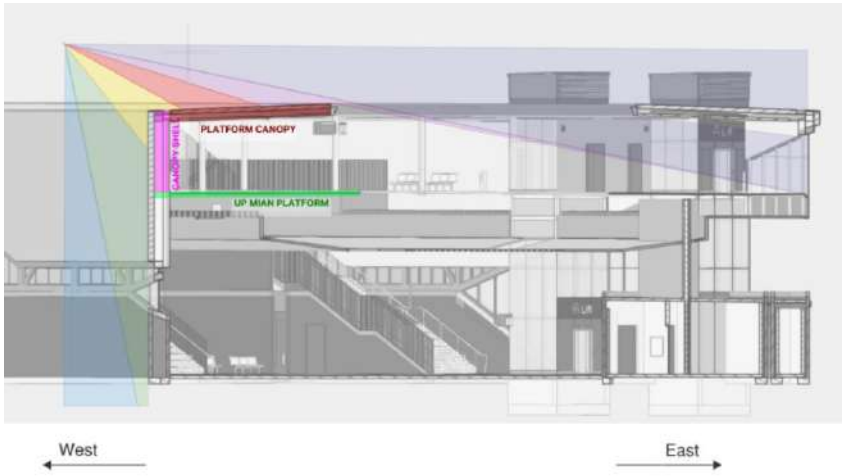

FIGURE 3-8 UP MAIN PLATFORM SAFE ZONE WESTERN RAIN ANGLES

Figure 3-9 shows that with the proposed canopy and platform design, rain from the West could penetrate the full depth of the Down Main Platform Safe Zone depending on the rainfall angle.

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 areas encompassed by the red and yellow rain angles typically occur 51.1% of the time it is raining from the West (less than approximately 3.6% of the time annually).

The seating and stairs near the Down Main Platform Safe Zone may therefore be impacted by Western Rain for a small percentage of the year depending on the rainfall angle.

FIGURE 3-9 DOWN MAIN PLATFORM SAFE ZONE WESTERN RAIN ANGLES

Northern Rain

Figure 3-10 shows that with the proposed canopy and platform design, rain from the North could penetrate the full depth of the Up Main Platform Safe Zone 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).

The seating and stairs near the Up Main Platform Safe Zone may therefore be impacted by Northern rain for a small percentage of the year depending on the rainfall angle.

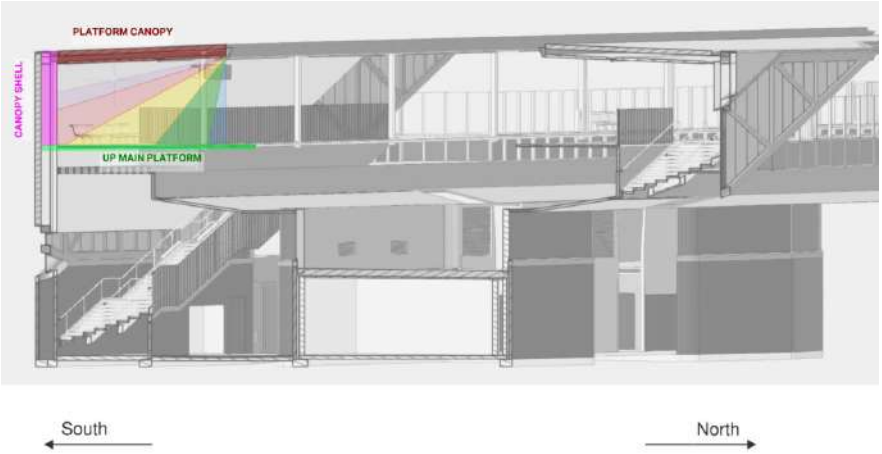

FIGURE 3-10 UP MAIN PLATFORM SAFE ZONE NORTHERN RAIN ANGLES

Figure 3-11 below shows how the Northern rain may interact with the canopy shell that wraps around the portion of the Down Main platform above the concourse. Based on the diagram, rain from the North is not expected to affect the Down Main Platform Safe Zone.

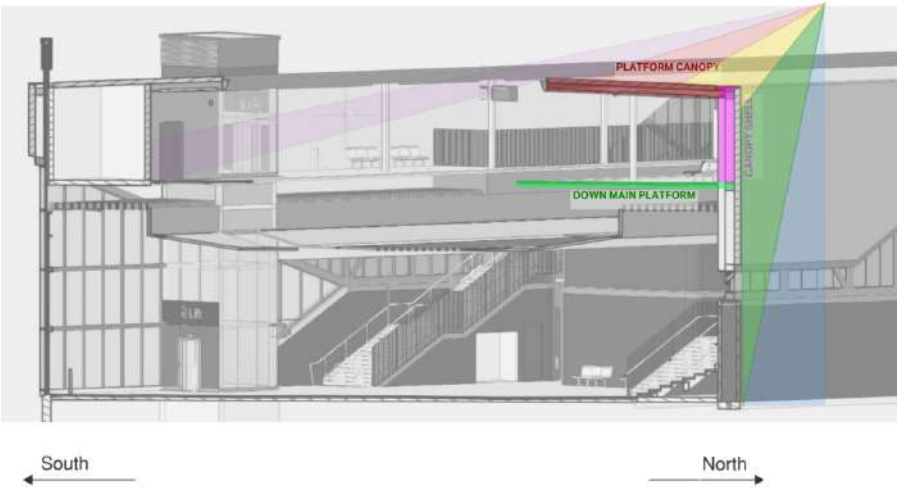

FIGURE 3-11 DOWN MAIN PLATFORM SAFE ZONE NORTHERN RAIN ANGLES

3.3.3.2 Lift Zone

Figure 3-12 demonstrates how the prevailing rain directions will likely interface with each lift entry zone.

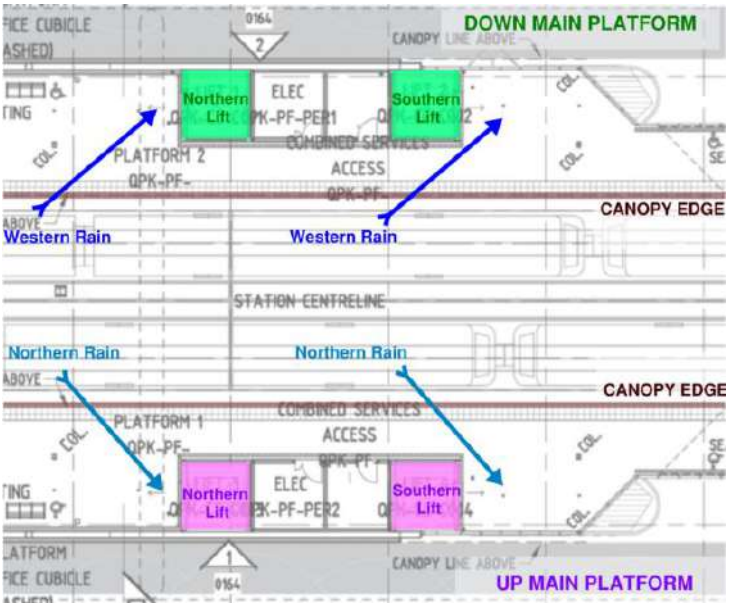

FIGURE 3-12 PLAN VIEW OF RAIN DIRECTION

Western Rain

Figure 3-13 below analyses the impact of Western on the Up Main Platform Southern lift entry area with the cover of the transparent screen and metal sheeting in the architectural canopy shell.

From this assessment, rain from the West is unlikely to have an impact on the Up Main Platform Southern Lift Zone. An analysis of the Western Rain on the Northern lift entry on the Up Main Platform would result in a similar rainfall outcome.

FIGURE 3-13 UP MAIN PLATFORM WESTERN RAIN ANGLES

Figure 3-14 below analyses how Western rain may fall on the Down Main Platform lift entry area with the cover of the transparent screen and metal sheeting in the architectural canopy shell.

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 areas encompassed by the red and yellow rain angles typically occur 51.1% of the time it is raining from the West (less than approximately 3.6% of the time annually).

The Northern and Southern lift entry zones may therefore be impacted by Western rain for a small percentage of the year depending on the rainfall angle.

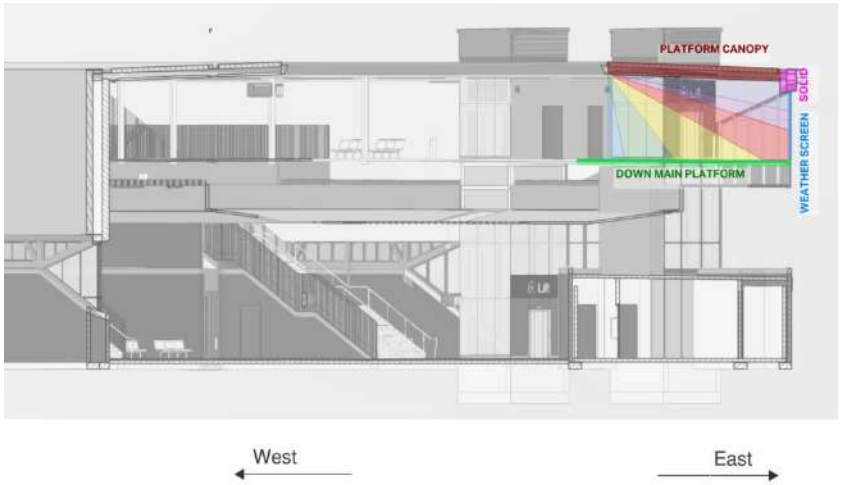

FIGURE 3-14 DOWN MAIN PLATFORM WESTERN RAIN ANGLES

Northern Rain

Figure 3-15 analyses how Northern rain may fall onto the Up Main Platform Southern lift entry area with the cover of the transparent screen and metal sheeting in the architectural canopy shell.

The 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 areas encompassed by the green and yellow rain angles typically occur 74.7% of the time it is raining from the West (less than approximately 5.3% of the time annually).

The diagram indicates that the Southern lift entry will be affected by rain, depending on the rainfall angle. An analysis of the Northern Rain on the Northern lift entry on the Up Main Platform would result in a similar rainfall outcome.

FIGURE 3-15 UP MAIN PLATFORM NORTHERN RAIN ANGLES

Figure 3-16 analyses how Northern rain may fall onto the Down Main Platform Southern lift entry area with the cover of the transparent screen and metal sheeting in the architectural canopy shell.

From this view, rain from the North is unlikely to affect the Down Main Platform Southern Lift Zone. An analysis of the Northern Rain on the Northern lift entry on the Down Main Platform would result in a similar rainfall outcome.

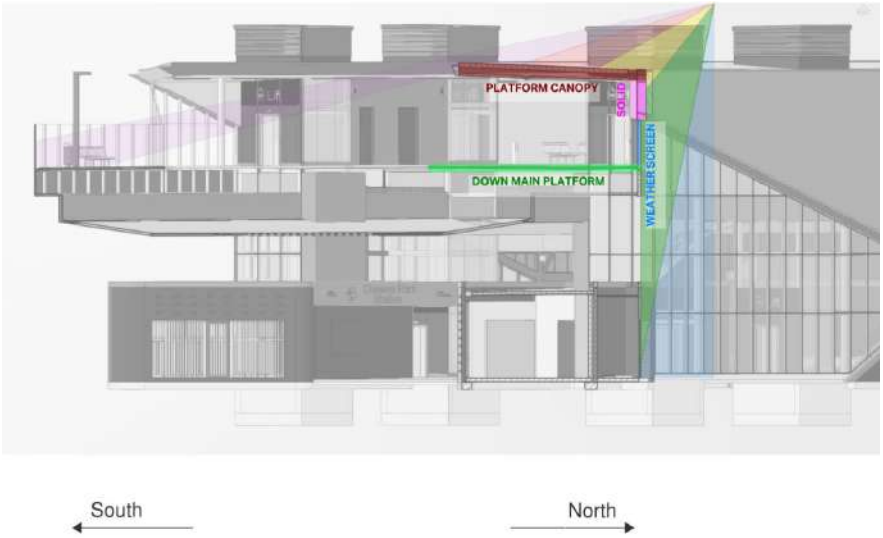

FIGURE 3-16 DOWN MAIN PLATFORM NORTHERN RAIN ANGLES

3.3.3.3 Pedestrian Stairs

Western Rain

Figure 3-17 shows the architectural canopy shell has a metal sheeting (pink) and a perforated screen (blue) adjacent to the Up Main Platform Pedestrian Stairs. The perforated screen is expected to provide some protection to the stairs from Western rain but will not completely prevent rain from entering. However, this will only occur for the small percentage of the year that it rains from the West (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 UP MAIN PLATFORM PEDESTRIAN STAIRS WESTERN RAIN ANGLES

Figure 3-18 demonstrates that the Western rain may penetrate the full depth of the pedestrian stairs on Down Main Platform depending on the rainfall angle. Rain from the West direction at 9.5m high will most likely fall at the red and yellow rain angles as identified by the percentages above in section 3.3.1. The areas

encompassed by the red and yellow 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).

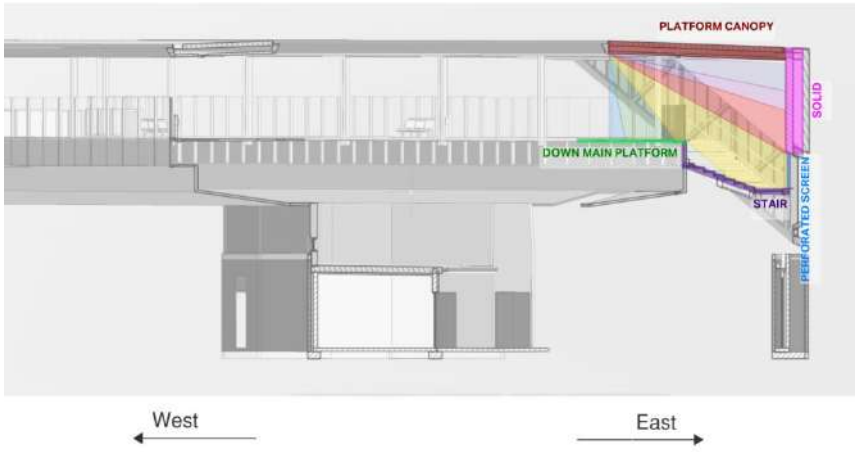

FIGURE 3-18 DOWN MAIN PLATFORM PEDESTRIAN STAIRS WESTERN RAIN ANGLES

Northern Rain

Figure 3-19 demonstrates it is likely that the Northern rain enters the full depth of the pedestrian stairs on the Up Main Platform. Rain from the North direction at 9.5m high will most likely fall at the red 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 5.1% of the time annually).

FIGURE 3-19 UP MAIN PLATFORM PEDESTRIAN STAIRS NORTHERN RAIN ANGLES

Figure 3-20 demonstrates that the canopy shell has metal sheeting (pink) and a perforated screen (blue) adjacent to the Down Main Platform Pedestrian Stairs, this is expected to provide some protection to the stairs from Northern rain but will not completely prevent rain from entering. However, this will only occur for the small percentage of the year that it rains from the North (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.

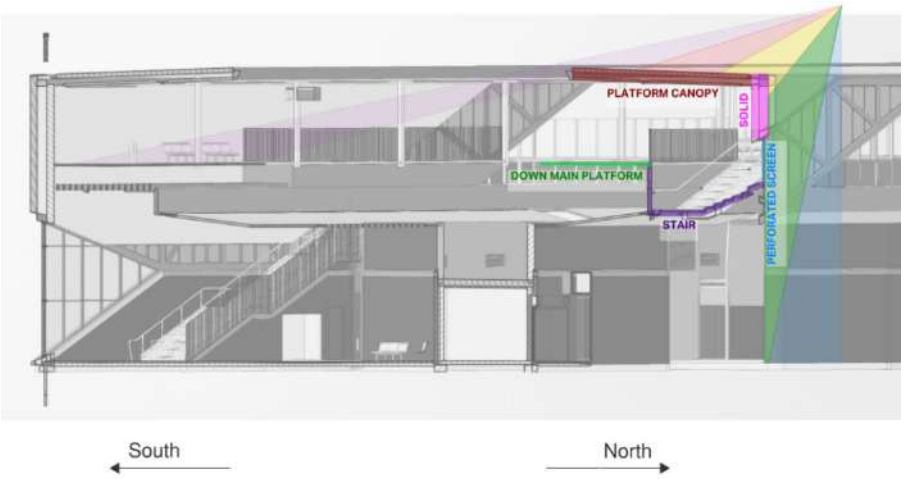

FIGURE 3-20 DOWN MAIN PLATFORM PEDESTRIAN STAIRS NORTHERN RAIN ANGLES

3.3.3.4 Station Entry and Foyer

Western Rain

Figure 3-21 demonstrates how Western rain may land on the station building entry way. The concourse entry in this design has the cover of the overhead platform and tracks denoted by the pink markups respectively.

Rain from the West direction will most likely fall at the green and yellow rain angles as identified by the percentages above in section 3.3.1. The roof of the concourse building, and overhead platform and tracks will provide protection to the station entrance from the Western rain. Based on this assessment the Western rain is unlikely to impact the station entrance and foyer.

FIGURE 3-21 STATION ENTRY AND FOYER WESTERN RAIN ANGLES

1.0 Northern Rain

Figure 3-22 demonstrates how Northern rain may land on the station building entry way.

Rain from the North will most likely fall at the green and blue rain angles. The roof of the concourse building and overhead platform and tracks will provide protection to the station entrance from Northern rain. Based on this assessment the Northern rain is unlikely to impact the station entrance and foyer.

FIGURE 3-22 STATION ENTRY AND FOYER NORTHERN RAIN ANGLES

3.4 Wind Protection

The aim of this analysis is to provide advice on the probable wind direction and its impact on waiting for 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 have 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 **Error! Reference source not found.** 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.

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.

[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

Scope Item	Comments
22.4-5-3-18	*Wind study demonstrating that the design of station 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, as per Green Star v1.1 requirements, at least 10% of the platform area is protected from prevailing winds due to the canopy shell.
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 and metal screening adjacent to the lifts, there is 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, below listed assessment areas of both platforms and the station building were identified for rain protection:

- Platform (Section 3.4.2.1)
- 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 that 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°) accounts for 11.2% of the year
- South (180° to 190°) accounts for 9.6% of the year
- Southwest (220° to 240°) accounts for 12.7% of the year

3.4.2.1 Platforms

Figure 3-23 indicates that the sections of the platform that extend beyond the cover of the canopy shell are relatively exposed for each of the prevailing wind directions. Some protection may be available by the platform barriers, provided the protection is not permeable. The two canopy shells appear to provide considerable protection from prevailing winds to the sections of the platforms that they envelop.

The wind from the South at the platform height of 9.5m is considered comfortable for short periods of time according to the Lawson comfort criteria. However, more than 30% of the wind from the East, and more than 45% of the wind from the Southwest could reach uncomfortable speeds for occupants (equal to speeds greater than 6m/s).

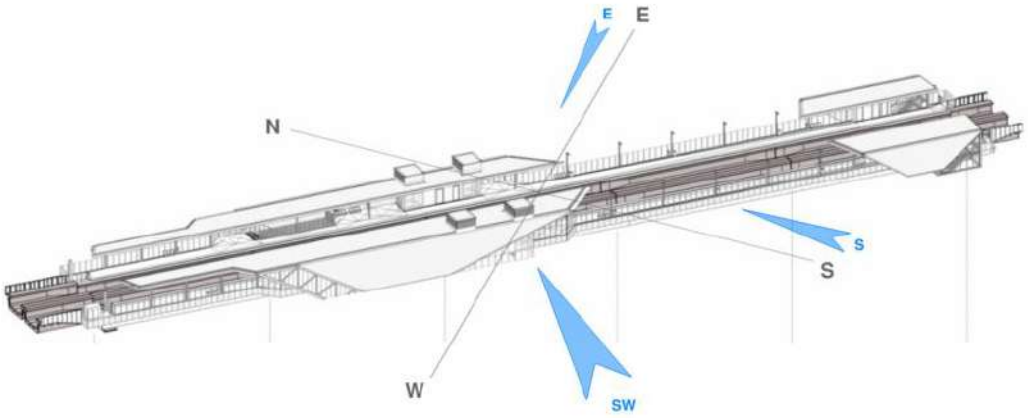

FIGURE 3-23 PREVAILING WIND DIRECTIONS ON PLATFORM LEVEL

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

TABLE 3-11 – PREVAILING WIND DIRECTION AND PROTECTION MECHANISMS

Prevailing Wind Direction	Percent of Annual Hours with Wind	Acceptable Wind Speed per Lawson criteria?	Wind Protection provided to the uncomfortable wind?	Protection Mechanism
East	11.2%	No	Yes	Canopy shell and platform barriers
South	9.6%	No	Yes	Canopy shell and platform barriers
Southwest	12.7%	No	Yes	Canopy shell and platform barriers

3.4.2.2 Station Entry and Foyer

Figure 3-24 demonstrates how the prevailing wind directions may affect the concourse station entrance. The station entry could see a crosswind from the Southwest prevailing wind, as well as the potential for the East

and Southern winds to penetrate the station entry. However, typically the wind from each of these directions is at a comfortable speed, in accordance with the Lawson comfort criteria.

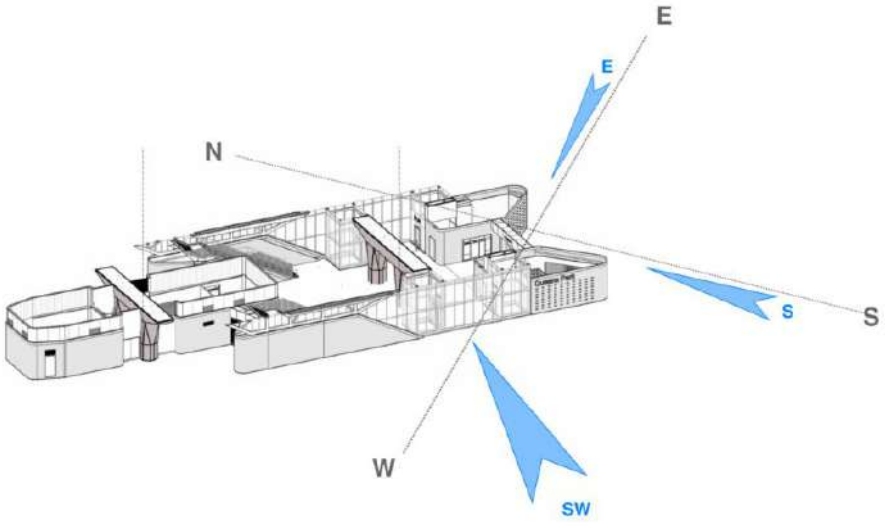

FIGURE 3-24 PREVAILING WIND DIRECTIONS ON GROUND FLOOR CONCOURSE LEVEL

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

TABLE 3-12 – PREVAILING WIND DIRECTION AND PROTECTION MECHANISMS

Prevailing Wind Direction	Percent of Annual Hours with Wind	Acceptable Wind Speed per Lawson criteria?	Wind Protection provided to the uncomfortable wind?	Protection Mechanism
East	11.2%	Yes	No	-
South	9.6%	Yes	No	-
Southwest	12.7%	Yes	Yes (potential crosswind)	Station building

ARMADALE LINE UPGRADE ALLIANCE

Appendix A
PREVIOUS ASSESSMENTS

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Notice of Advice

Attention	Ben Marshall	File No.	V1
Company	AECOM	Date	09-May-2022
CC		Total Page	22
Project Name	ALXR Detailed Design	Project No.	60676692
From	Laura Donaldson & Bronte Kerley		
Service	Queens Park Station Reference Design Environmental Comfort Desktop Study		

The following NOA provides an initial desktop study into the external environmental comfort at Queens Park Station. The aim of the study is to provide an overview of any risk areas where passengers may feel uncomfortable as a result of wind and rain. The assessments do not consider safety impacts.

Where applicable, Green Star – Railway Stations will be 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 represents best practice throughout the life cycle of the built environment. Green Star – Railway Stations is a customisation of Green Star – Design & As Built v1.2 and has been prepared for use on above ground and underground railway stations through a collaboration with Rail Projects Victoria (RPV).

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1.0 Project Details

Weather data from Jandakot weather station was obtained from the Bureau of Meteorology for the analysis. Queens Park Station is approximately 11km from the Jandakot weather station.

2.0 Rain Assessment

In Jandakot, it rains for 7% of the year. Table 1 and Table 2 below show the times of year and the time of day when this rain is 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 1 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 2 Frequency of Rainfall Based on Season

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%

To consider the angle that rain may fall, the wind direction is taken into account. As per the weather data obtained from Jandakot weather station, 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 prevailing wind directions are shown in Figure 1 and Figure 2 below.

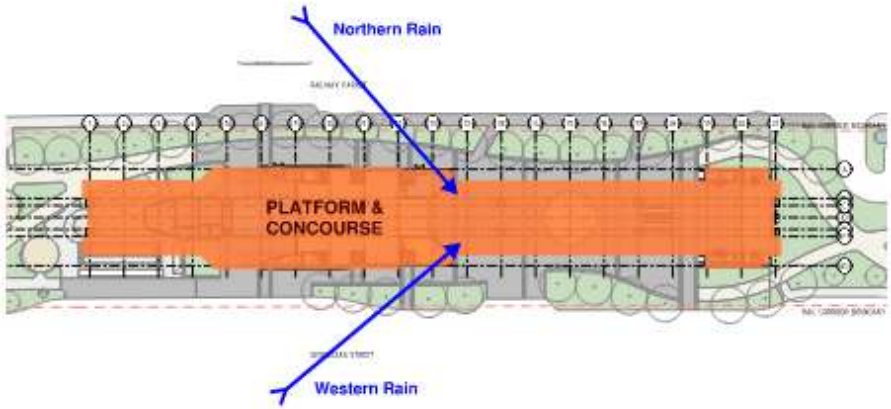


Figure 1 Plan

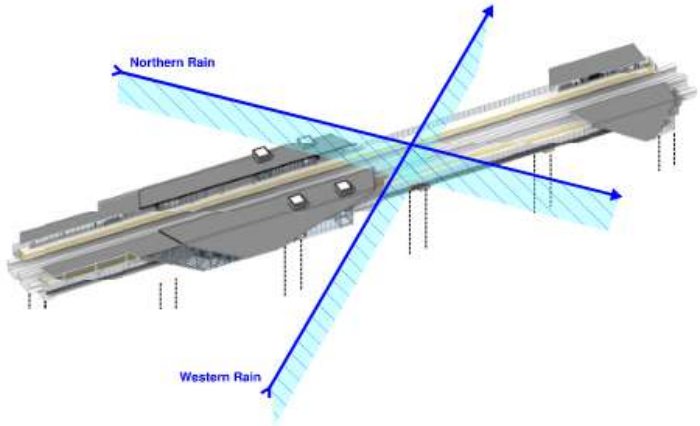


Figure 2 Axonometric (visual representation)

Please note the section and elevation views provided in Table 4 and Table 6 below do not align true with the West axis or the North axis (the directions at which the rain will fall). Therefore, two assessments have been undertaken in order to best understand how the rain profiles will interact with the station (one on the North East – South West axis and one on the South East – North West Axis). The assessments should be read in conjunction to obtain a full understanding of the potential rain impacts.

Figure 3 and Figure 4 below highlight the station's key points of interest assessed during the rain and wind analysis. Each platform was analysed individually with the North East platform being referred to as Platform 1 and the South West platform referred to as Platform 2.

Figure 3 Site Points of Interest (Ground Floor Concourse)

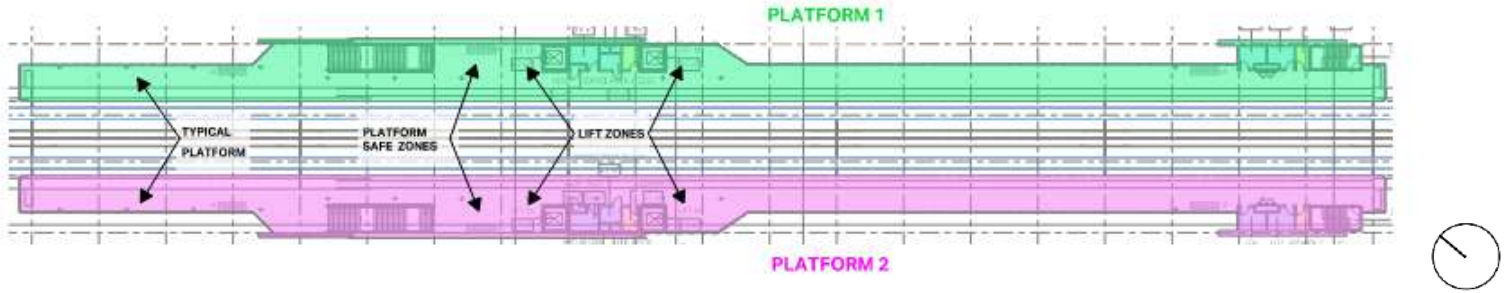


Figure 4 Site Points of Interest (Platforms)

For the South East – North West Axis view analysis, where the site points of interest that are enveloped by the architectural canopy shell, only one platform is shown in the diagrams below. Due to the configuration of the station platforms and their canopy shell's in relation to the prevailing rain directions, each rain direction can only penetrate under the canopy of one platform. The relationship between platform, prevailing rain direction and section view selected for analysis is outlined in Figure 5.

For the Northern rain, only platform 2 is impacted in areas where the canopy shell encloses the platform. This is shown in Section A in the diagrams below (Table 4 and Table 6).

For the Western rain, only platform 1 is impacted in areas where the canopy shell encloses the platform. This is shown in Section B in the diagrams below (Table 4 and Table 6).

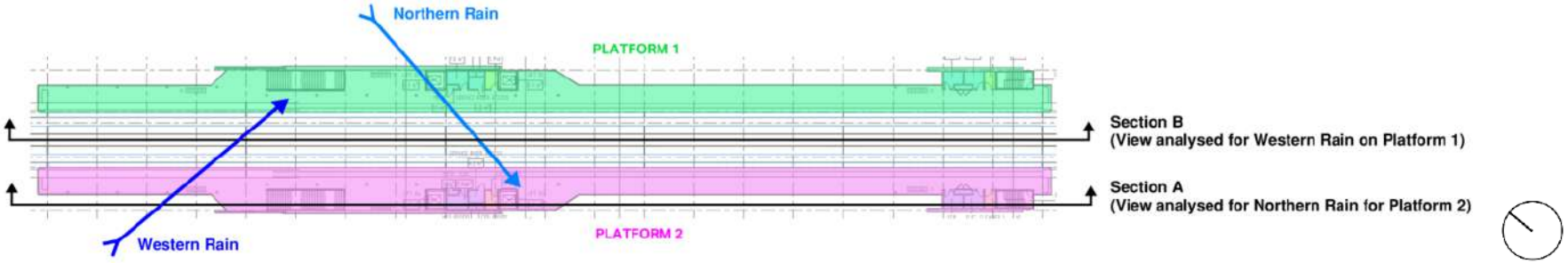


Figure 5 View Selection for Analysis Informed by Most Impactful Rain Direction

Following obtaining the prevailing wind directions, the wind speed in these directions was analysed to determine the likely rainfall angle.

2.1.1 Western Rain

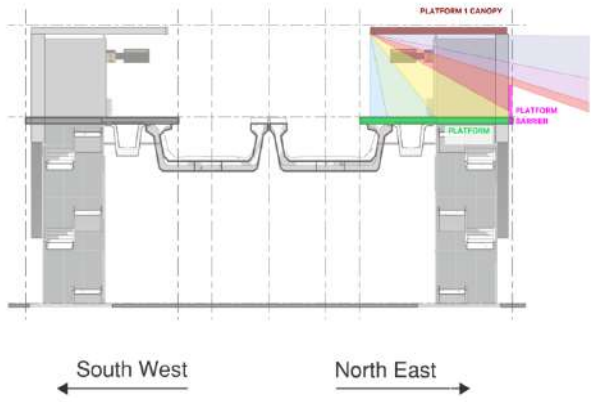
Rain from the western direction is likely to fall from the following angles at 1 metre and 9.5 metres high (these two heights have been selected as a representation of ground level wind speeds and platform height windspeeds):

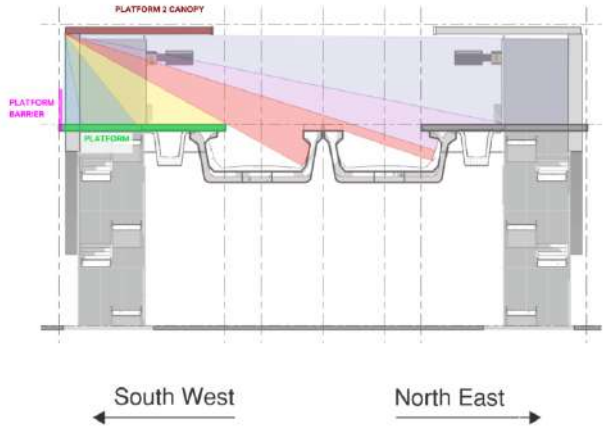
Table 3 Western Rain Frequency Array at 1m and 9.5m

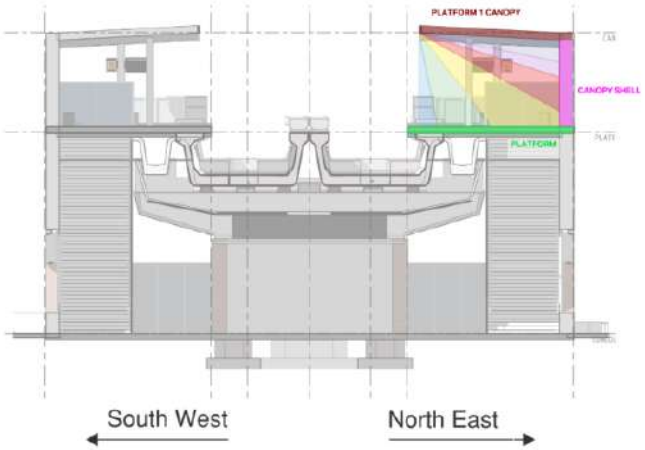
1 metre (ground level)	9.5 metres above ground level (approximate platform height)
• 0° to 11° - less than 1% • 11° to 17° (purple) – 2.2% • 17° to 28° (red) – 17.4% • 28° to 50° (yellow) – 37.6% • 50° to 78° (green) – 32.9% • 78° to 90° (blue) – 9.7%	• 0° to 11° (grey) - less than 10% • 11° to 17° (purple)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

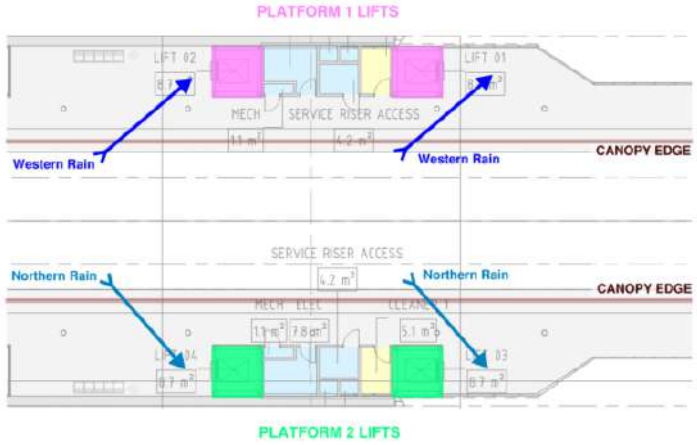
The increased likelihood of frequency is also reflected in increased colour opacity.

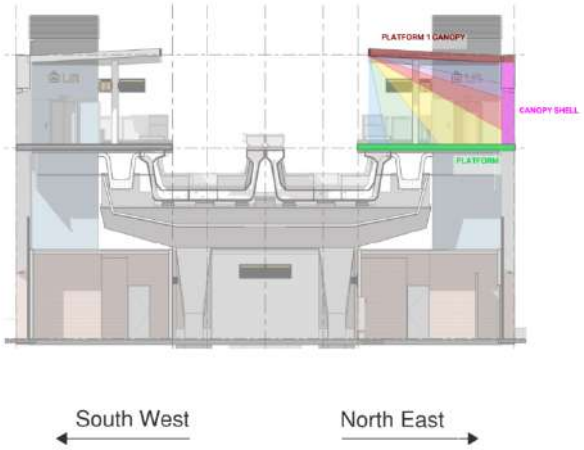
Table 4 Western Rain Desktop Study

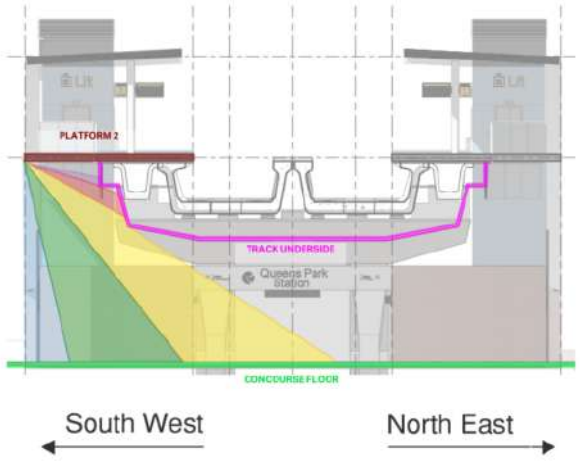
Platform Assessment (Typical Platform) (9.5m Rain Profile)	**Platform 1**  *Drawing received (29/04/22)*	The diagram shows that with the proposed canopy and platform barrier, rain from the West could penetrate the full depth of Platform 1 depending on the rainfall angle. Rain from the West direction at 9.5m high will most likely fall at the red and yellow rain angles as identified by the percentages above.

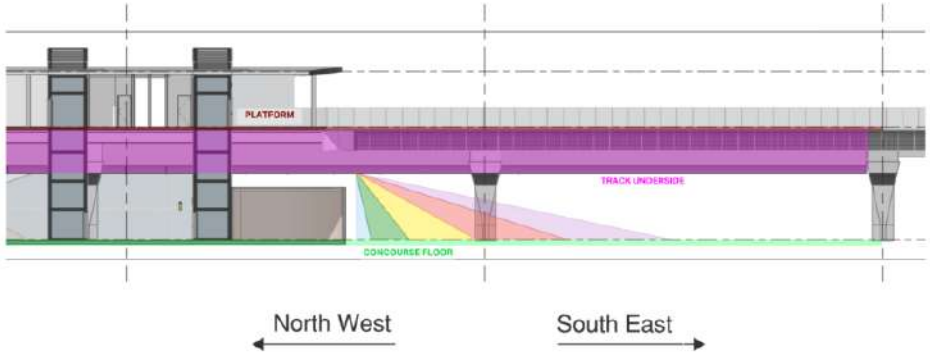
	Platform 2  *Drawing received (29/04/22)*	The diagram shows that with the proposed canopy and platform barrier, rain from the West could penetrate between the canopy-barrier gap and reach the full depth of Platform 2 depending on the rainfall angle. Rain from the West direction at 9.5m high will most likely fall at the red and yellow rain angles, for 26.5% and 24.6% of the time when it is raining respectively. Both platforms will most likely see the proposed seating be affected by rain.
	Section B - Platform 1  *Drawing received (29/04/22)*	Analysing the South West (Section B) elevation, rain could potentially penetrate under the Platform 1 canopy (under the edge adjacent to the rail corridor) for a distance of approximately 20m. This approximation is measured to the end of the purple zone, so there is a possibility of the rain falling at an angle that penetrates within the grey zone. The diagram to the left is a representation of how the rain may interact, from this view, along any section of the platform extending beyond the canopy shell envelope. Rain from the West direction will most likely fall at the red and yellow rain angles. Please note, as mentioned above, the section and elevation views provided do not align true with the West axis. Therefore, this image should be read in conjunction with the diagrams above. An analysis for the Western Rain on the Typical Platform area on Platform 2 would result in a similar rainfall outcome.

Platform Assessment (Platform Safe Zones) (9.5m Rain Profile)	**Platform 1**  *Drawing received (29/04/22)*	The diagram shows that with the proposed canopy and canopy shell that wraps around the portion of the platform above the concourse, rain from the West could penetrate the full depth of Platform 1 Safe Zone depending on the rainfall angle. Rain from the West direction at 9.5m high will most likely fall at the red and yellow rain angles as identified by the percentages above. The high slanted canopy could expose more of the platform to the higher probability red and yellow rain angles. The areas encompassed by the purple, red and yellow rain angles may see a 70.9% likelihood of rain - which is inclusive of all angled zones before it.
	Platform 2  *Drawing received (29/04/22)*	The diagram shows how the Western rain may interact with the proposed canopy and canopy shell that wraps around the portion of the platform above the concourse. From this view, rain from the West will not affect the Platform 2 Safe Zone.

	Section B - Platform 1  *Drawing received (29/04/22)*	Analysing the South West (Section B) elevation, rain could potentially penetrate under the Platform 1 canopy shell (under the edge adjacent to the rail corridor) for up to a distance of approximately 20.5m. This approximation is measured to the end of the purple zone, so there is a possibility of the rain falling at an angle that penetrates within the grey zone. The diagram to the left is a representation of how the rain may interact, from this view, along any section of Platform 1 enveloped by the canopy shell. Rain from the West direction will most likely fall at the red and yellow rain angles with respective frequencies of 26.5% and 24.6% of the time when rain is falling. The seating and stairs near the Platform Safe Zone may still be impacted by rain depending on the rainfall angle. Please note, as mentioned above, the section and elevation views provided do not align true with the West axis. Therefore, this image should be read in conjunction with the diagrams above.
Platform Assessment (Lift Zones) (9.5m Rain Profile)	**Plan View of Rain Directions**  *Drawing received (29/04/22)*	The diagram to the left demonstrates how the prevailing rain directions will likely interface with each lift entry zone. The Western rain will only penetrate under the canopy of Platform 1 and so will only affect Platform 1 Lift Zones. But it is worth noting how the angle at which rain from the West interfaces with each lift landing area is different.

	Platform 1  *Drawing received (29/04/22)*	The diagram to the left analyses how Western rain may fall onto the Platform 1 Southern lift entry area with the cover of the architectural canopy shell. Rain from the West direction at 9.5m high will most likely fall at the red and yellow rain angles. The diagram indicates that the Southern lift entry will be affected by rain, depending on the rainfall angle. An analysis for the Western Rain on the Northern lift entry on Platform 1 would result in a similar rainfall outcome.
	Platform 2  *Drawing received (29/04/22)*	The diagram to the left analyses how Western rain may fall onto the Platform 2 Southern lift entry area with the cover of the architectural canopy shell. From this view, rain from the West will not affect the Platform 2 Southern Lift Zone. An analysis for the Western Rain on the Northern lift entry on Platform 2 would result in a similar rainfall outcome.

	Section B – Platform 1 Lifts  *Drawing received (29/04/22)*	Analysing the South West (Section B) elevation, rain could potentially penetrate under the edge of the Platform 1 canopy shell. This could impact both the Northern and Southern Lift Entry Zones. The diagram to the left is a representation of how the rain may interact, at these two areas of interest, from this view. Rain from the West direction will most likely fall at the red and yellow rain angles with respective frequencies of 26.5% and 24.6% of the time when rain is falling.
Station Building Assessment (1m Rain Profile)	**Station Entry –Section View**  *Drawing received (29/04/22)*	The section view to the left demonstrates how Western rain may land on the station building entry way. The concourse entry in this design has the cover of the overhead platform and tracks denoted by the brown and pink markups respectively. Rain from the West direction will most likely fall at the green and yellow rain angles, 32.9% and 37.6%, at this height, this could possibly impact the concourse floor just prior to the station entry. Please refer to the diagram below for further detail.

	Station Entry – Elevation View  *Drawing received (29/04/22)*	The diagram to the left shows the South West elevation and demonstrates how rain may affect the station building entry way. Rain from the West direction will most likely fall at the green and yellow rain angles with a respective rate of 32.9% and 37.6%. There is a low possibility of rain penetrating the concourse building due to the orientation of the entry way in relation to the Western rain. Please note, as mentioned above, the section and elevation views provided do not align true with the West axis. Therefore, this image should be read in conjunction with the diagram above.

2.1.2 Northern Rain

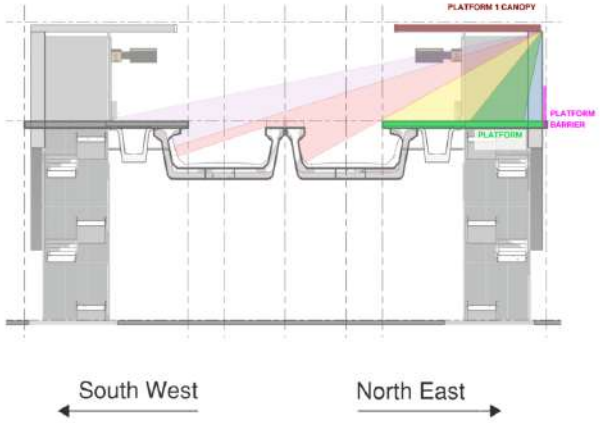
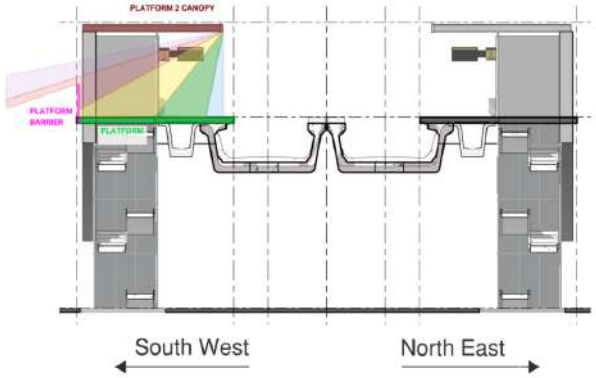
Rain from the northern direction is likely to fall from the following angles at 1 metre and 8 metres high:

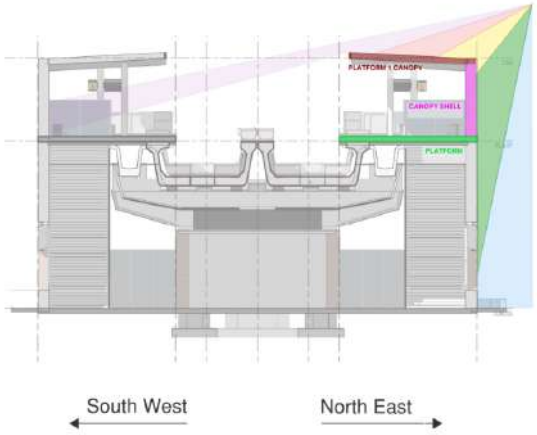
Table 5 Northern Rain Frequency Array at 1m and 9.5m

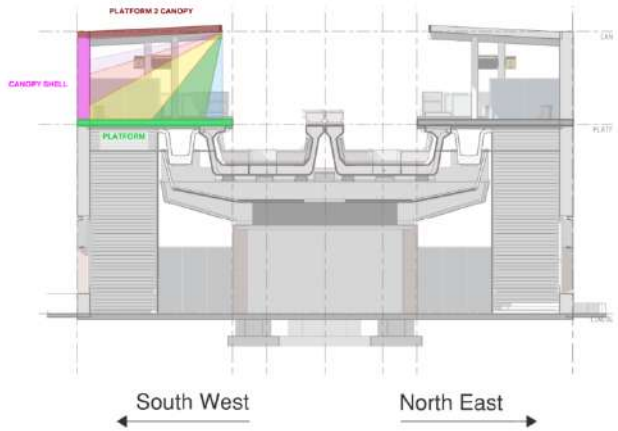
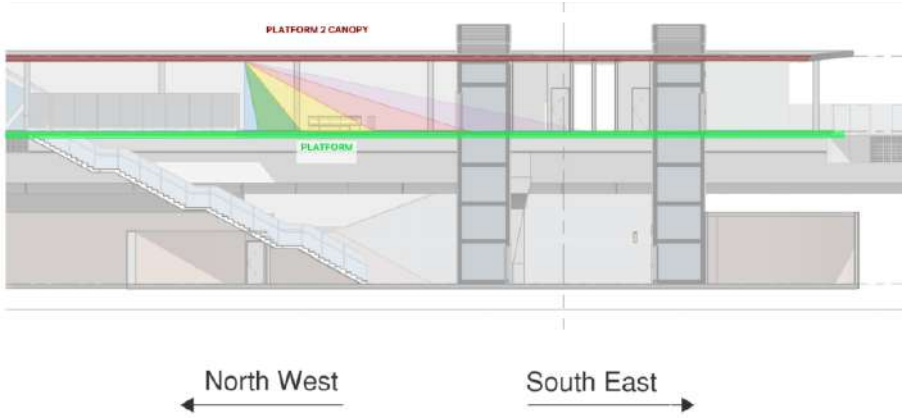
1 metre above ground level	8 metres above ground level
• 0° to 11° - less than 1% • 11° to 17° (purple) – 1.1% • 17° to 28° (red) – 3.1% • 28° to 50° (yellow) – 13.4% • 50° to 78° (green) – 60.4% • 78° to 90° (blue) – 21.9%	• 0° to 11° - less than 2.2% • 11° to 17° (purple) – 4.0% • 17° to 28° (red) – 10.3% • 28° to 50° (yellow) – 33.7% • 50° to 78° (green) – 41% • 78° to 90° (blue) – 8.7%

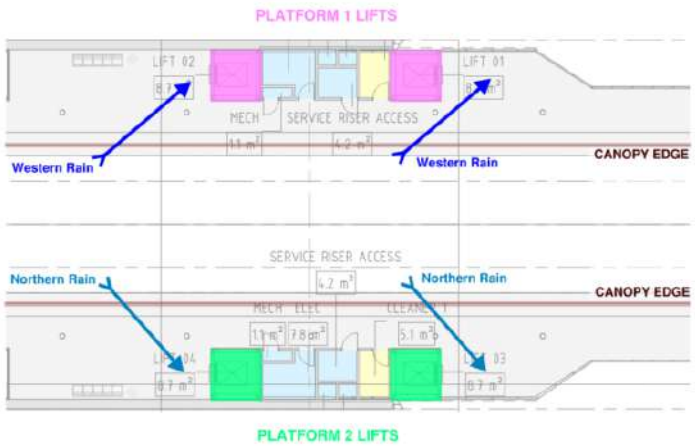
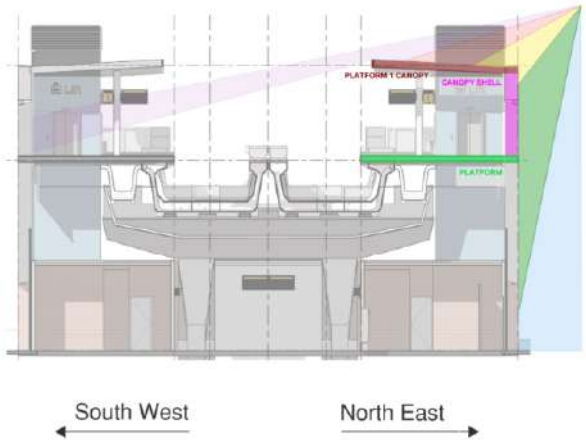
The increased likelihood of frequency is also reflected in increased colour opacity.

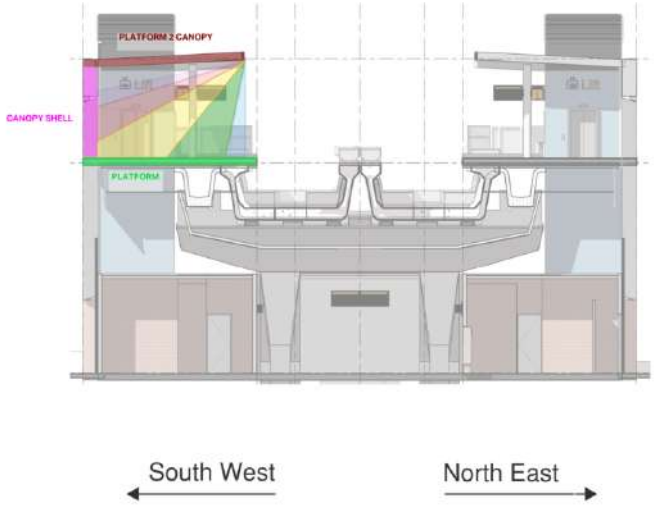
Table 6 Northern Rain Desktop Study

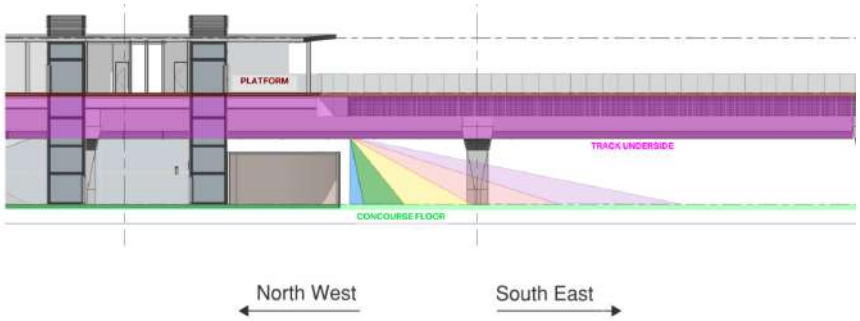
Platform Assessment (Typical Platform) (9.5m Rain Profile)	**Platform 1**  *Drawing received (29/04/22)*	The diagram shows that with the proposed canopy and platform barrier, rain from the North could penetrate between the canopy-barrier gap and reach the full depth of Platform 1 depending on the rainfall angle. Rain from the North direction at 9.5m high will most likely fall at the green and yellow rain angles, for 41% and 33.7% of the time when it is raining respectively.
	Platform 2  *Drawing received (29/04/22)*	The diagram shows that with the proposed canopy and platform barrier, rain from the North could penetrate the full depth of Platform 2 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. Both platforms will most likely see the proposed seating be affected by rain.

	Section A – Platform 2  *Drawing received (29/04/22)*	Analysing the South West (Section A) elevation, rain could potentially penetrate under the Platform 2 canopy (under the edge adjacent to the rail corridor) for a distance of approximately 20m. The diagram to the left is a representation of how the rain may interact, from this view, along any section of the platform extending beyond the canopy shell envelope. Rain from the North direction will most likely fall at the green and yellow rain angles. Please note, as mentioned above, the section and elevation views provided do not align true with the North axis. Therefore, this image should be read in conjunction with the diagrams above. An analysis for the Northern Rain on the Typical Platform area on Platform 1 would result in a similar rainfall outcome.
Platform Assessment (Platform Safe Zones) (9.5m Rain Profile)	**Platform 1**  *Drawing received (29/04/22)*	The diagram to the left shows how the Northern rain may interact with the proposed canopy and canopy shell that wraps around the portion of the platform above the concourse. From this view, rain from the North will not affect the Platform 1 Safe Zone.

	Platform 2  *Drawing received (29/04/22)*	The diagram shows that with the proposed canopy and canopy shell that wraps around the portion of the platform above the concourse, rain from the North could penetrate the full depth of Platform 2 Safe Zone 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. The high slanted canopy could expose more of the platform to the higher probability green and yellow rain angles. The areas encompassed by the red, green and yellow rain angles may see an 85% likelihood of rain - which is inclusive of all angled zones before it.
	Section A – Platform 2  *Drawing received (29/04/22)*	Analysing the South West (Section A) elevation, rain could potentially penetrate under the Platform 2 canopy shell (under the edge adjacent to the rail corridor) for up to a distance of approximately 20.5m. The diagram to the left is a representation of how the rain may interact, from this view, along any section of Platform 2 enveloped by the canopy shell. Rain from the North direction will most likely fall at the green and yellow rain angles with respective frequencies of 41% and 33.7% of the time when rain is falling. The seating and stairs near the Platform Safe Zone may still be impacted by rain depending on the rainfall angle. Please note, as mentioned above, the section and elevation views provided do not align true with the North axis. Therefore, this image should be read in conjunction with the diagrams above.

Platform Assessment (Lift Zone) (9.5m Rain Profile)	**Plan View of Rain Directions**  *Drawing received (29/04/22)*	The diagram to the left demonstrates how the prevailing rain directions will likely interface with each lift entry zone. The Northern rain will only penetrate under the canopy of Platform 2 and so will only affect Platform 2 Lift Zones. But it is worth noting how the angle at which rain from the North interfaces with each lift landing area is different.
	Platform 1  *Drawing received (29/04/22)*	The diagram to the left analyses how Northern rain may fall onto the Platform 1 Southern lift entry area with the cover of the architectural canopy shell. From this view, rain from the North will not affect the Platform 2 Southern Lift Zone. An analysis for the Northern Rain on the Northern lift entry on Platform 1 would result in a similar rainfall outcome.

	Platform 2  *Drawing received (29/04/22)*	The diagram to the left analyses how Northern rain may fall onto the Platform 2 Southern lift entry area with the cover of the architectural canopy shell. Rain from the North direction at 9.5m high will most likely fall at the green and yellow rain angles. The diagram indicates that the Southern lift entry will be affected by rain, depending on the rainfall angle. An analysis for the Northern Rain on the Northern lift entry on Platform 2 would result in a similar rainfall outcome.
	Section B – Platform 2 Lifts  *Drawing received (29/04/22)*	Analysing the South West (Section B) elevation, rain could potentially penetrate under the edge of the Platform 2 canopy shell. This could impact both the Northern and Southern Lift Entry Zones. The diagram to the left is a representation of how the rain may interact, at these two areas of interest, from this view. Rain from the North direction will most likely fall at the green and yellow rain angles with respective frequencies of 41% and 33.7% of the time when rain is falling.

Station Building Assessment (1m Rain profile)	**Station Entry – Section View**  *Drawing received (29/04/22)*	The section view to the left demonstrates how the Northern rain may land on the station building entry way. The concourse entry in this design has the cover of the overhead platform and tracks denoted by the brown and pink markups respectively. Rain from the North direction will most likely fall at the green and blue rain angles with a respective rate of 60.4% and 21.9%, this could possibly impact the concourse floor just prior to the station entry. Please refer to the diagram below for further detail.
	Station Entry – Elevation View  *Drawing received (29/04/22)*	The diagram to the left shows the South West elevation and demonstrates how rain may affect the station building entry way. Rain from the North direction will most likely fall at the green and blue rain angles, 60.4% and 21.9%, at this height. There is a low possibility of rain penetrating the concourse building due to the orientation of the entry way in relation to the Northern rain. Please note, as mentioned above, the section and elevation views provided do not align true with the North axis. Therefore, this image should be read in conjunction with the diagram above.

3.0 Wind Assessment

The analysis determined that there are three prevailing wind directions at Jandakot:

- 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

The Lawson[1] comfort criteria has been used in this assessment. The criteria is 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.

The windspeeds experienced at the 9.5m height of the platforms is considerably faster than the speeds seen at ground level. The height comparison is demonstrated, for each prevailing direction, in the diagrams below.

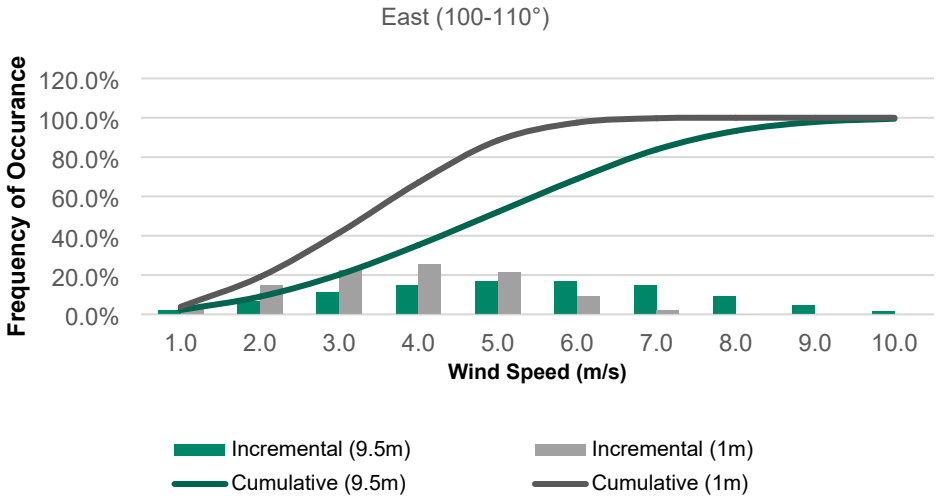


Figure 6 Wind speed comparison at heights of 1m and 9.5m (East wind)

[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

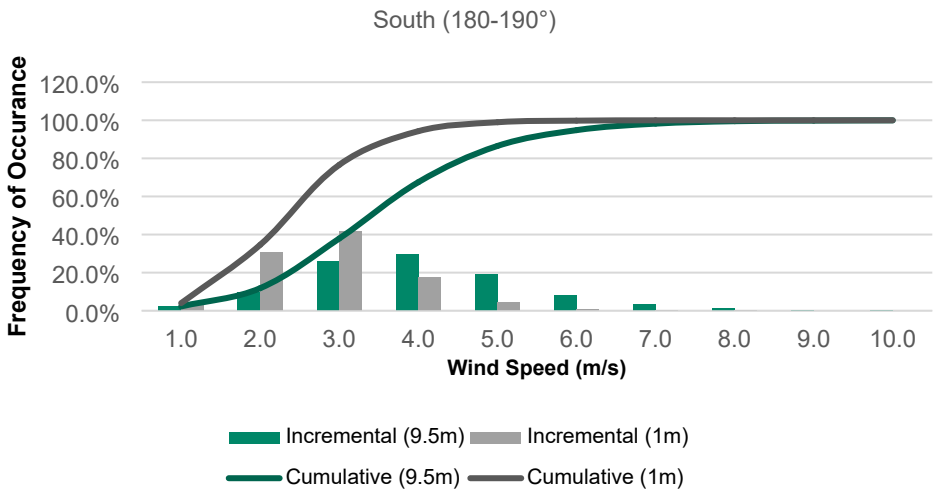


Figure 7 Wind speed comparison at heights of 1m and 9.5m (South wind)

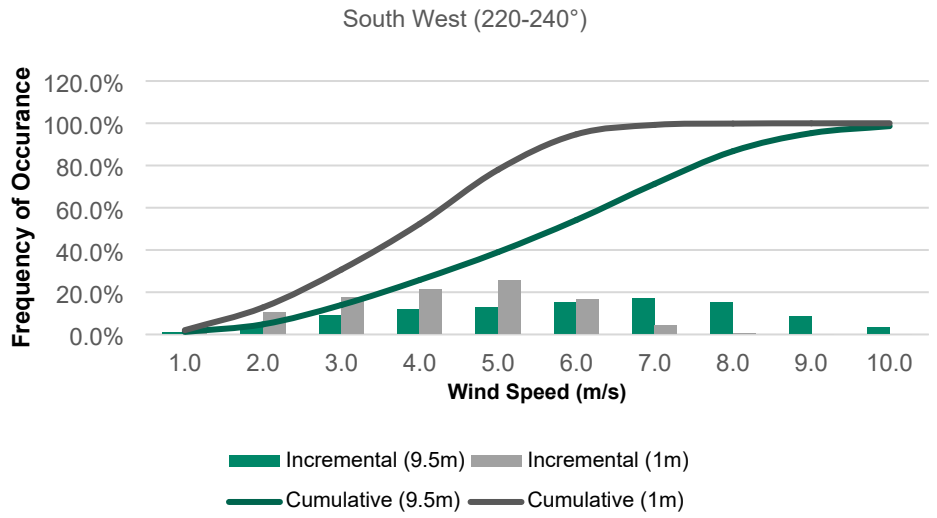


Figure 8 Wind speed comparison at heights of 1m and 9.5m (South West wind)

At ground level:

- The majority of wind from the Eastern direction (97.5%) has a speed of 6m/s or less.
- The majority of wind from the Southern direction (99.8%) has a speed of 6m/s or less.
- The majority of wind from the South Western direction (95%) has a speed of 6m/s or less.

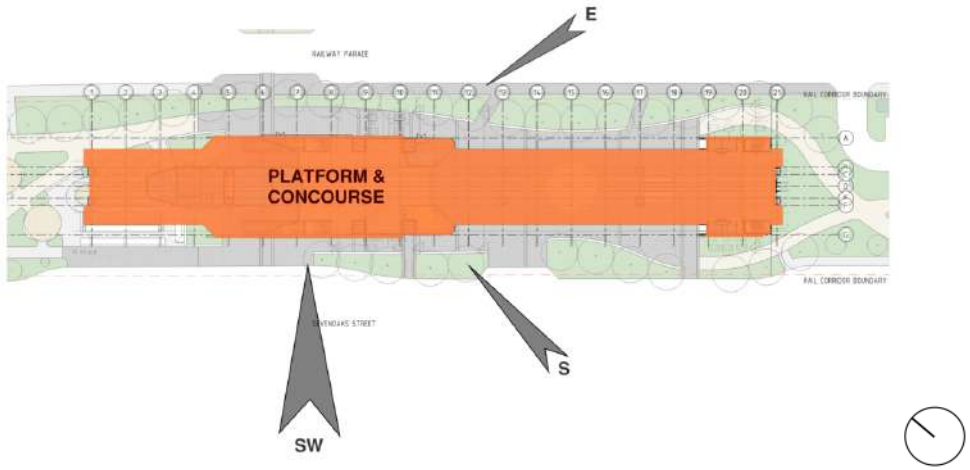
Each of the prevailing wind directions are considered comfortable for passengers sitting or standing for short periods of time under the Lawson comfort criteria.

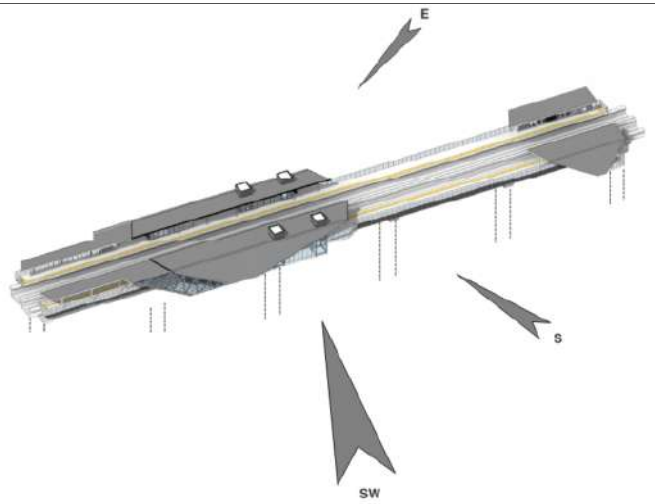
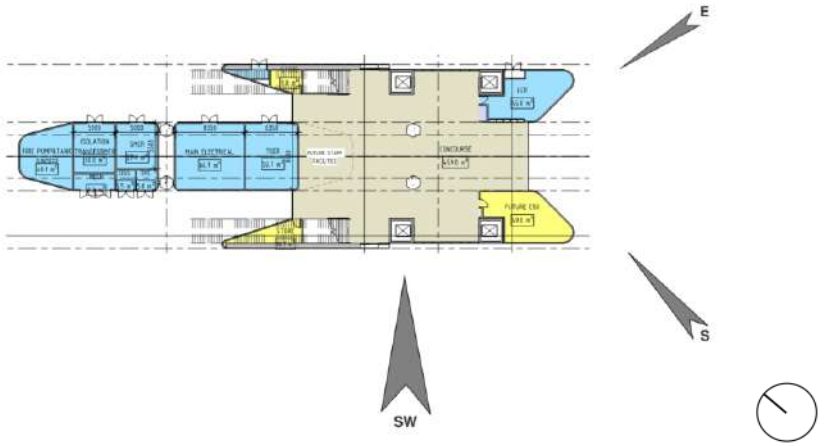
At platform level:

- 68.9% of wind from the Eastern direction has a speed of 6m/s or less.
- The majority of wind from the Southern direction (94.8%) has a speed of 6m/s or less.
- 54.2% of wind from the South Western direction has a speed of 6m/s or less.

A high proportion of the South West and East wind directions are considered uncomfortable for passengers sitting or standing for short periods of time under the Lawson comfort criteria. Furthermore, above 9.5m/s is considered uncomfortable for passengers who are leisurely walking.

Table 7 Wind Desktop Study

Platform Assessment	 *Drawing received (29/04/22)*	The diagram to the left indicates that the sections of platform that extend beyond the cover of the canopy shell are relatively exposed for each of the prevailing wind directions. Some protection may be available by the platform barriers, provided the protection is not permeable. The two canopy shells appear to provide considerable protection from prevailing winds to the sections of the platforms it envelopes. The wind from the South directions at the platform height of 9.5m is considered comfortable for short periods of time according to the Lawson comfort criteria. However, more than 30% of the wind from the East direction, and more than 45% of the wind from the South-West direction could reach uncomfortable speeds for occupants (equal to speeds greater than 6m/s).

	 *Drawing received (03/05/22)*	
Station Building Assessment	**Plan View (Concourse)**  *Drawing received (29/04/22)*	The diagram to the left demonstrates how the prevailing wind directions may affect the concourse station entrance. The station entry could see crosswind from the South West prevailing wind, as well as the potential for the East and Southern winds to penetrate the station entry. However, typically the wind from each of these directions are at a comfortable speed, in accordance with the Lawson comfort criteria.

Notice of Advice

Attention	Benjamin Hoy	File No.	V2
Company	AECOM	Date	02-Jun-2022
CC		Total Page	4
Project Name	ALXR Detailed Design	Project No.	60676692
From	Bronte Kerley		
Service	Queens Park Station Reference Design PDR Environmental Comfort		

The following NOA provides an initial desktop study into the external environmental comfort at Queens Park Station.

Environmental Comfort Assessment

A high-level environmental comfort study has been completed to assess solar access and control, natural lighting, solar reflection, rain protection and wind protection for commuter comfort. The assessments provide a high-level overview of the potential impacts the station designs have on comfort due to environmental factors. They do not consider safety impacts.

Where applicable, Green Star – Railway Stations 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 represents best practice throughout the life cycle of the built environment. Green Star – Railway Stations is a customisation of Green Star – Design & As Built v1.2 and has been prepared for use on above ground and underground railway stations through a collaboration with Rail Projects Victoria (RPV).

The environmental comfort was assessed at canopy covered platform areas, areas fully enclosed by the canopy (i.e. lift and safety zones), and at station entrances. It is assumed areas with no canopy cover are fully exposed to rain and solar exposure. A more detailed assessment will be completed in the next design stage.

Weather data from Jandakot weather station was obtained from the Bureau of Meteorology for the analysis of the wind and rain protection studies. Queens Park Station is approximately 11km from the Jandakot weather station.

<u>Wind Comfort and Protection</u>

To assess the impacts of wind on commuter comfort at Queens Park Station, average wind speeds and prevailing wind directions were assessed. There are three prevailing wind directions at Jandakot:

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

At platform level, wind protection is provided to the platform by the two architectural canopy shells which envelope the lift and stair entry to the platforms and the platform safe zones. Sections of platform that extend beyond the cover of the canopy shell are relatively exposed for each of the prevailing wind directions. Some protection may be available from the platform barriers, provided the protection is not permeable.

At ground level, the station entry could see crosswind from the South West prevailing wind, as well as the potential for the East and Southern winds to penetrate the station entry.

To determine whether the prevailing winds would cause discomfort for passengers at the station, the Lawson comfort criteria[1] has been used. The criteria is 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. Referring to the Lawson comfort criteria when evaluating windspeeds from prevailing wind directions found:

- At passenger height on the ground level, each of the prevailing wind directions are considered comfortable for passengers sitting or standing for short periods of time
- At passenger height on the platform level, more than 45% of the wind speeds from South West and more than 30% of wind speeds from the East, are above 6m/s and are considered uncomfortable for passengers sitting or standing for short periods of time

While some of the wind exceeds comfortable speeds on the platform, 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 canopy shell extends approximately 58 metres along the platform, sheltering approximately 38% of the platform from the uncomfortable windspeeds (from the South West and East) that are experienced at platform level.

Please note the above comments are based on comfort perspectives only and does not consider safety impacts such as wind gusts or wind tunnelling.

Rain Protection

To determine whether passengers will be impacted by rainfall on the newly proposed platform and station building, rain and wind data obtained from the Bureau of Meteorology was used to determine the prevailing wind direction and rain angle. The rain data indicates that:

- In Jandakot, it rains for 7% of the year
- The majority (54%) of rainfall occurs in winter
- The time of day at which rainfall occurs is evenly distributed throughout the day

To consider the angle that rain may fall, the wind direction was taken into account. As per the weather data obtained from Jandakot weather station, 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

Four points of interest (lift entry zones, patient safe zones, typical platform canopy and station entry) were analysed on each platform with height specific rain profiles from both the North and the West. This analysis found that only areas with both roof and wall cover provided sufficient protection from all likely rainfall angles. Key observations are noted below:

- Approximately 70m of the Northernmost platform has both roof and non-permeable wall cover, providing approximately 46% of the platform with protection from the Northern rain.
- Rain from the North may penetrate the full depth of the Southernmost platform.
- Approximately 70m of the Southernmost platform has both roof and non-permeable wall cover, providing 46% of the platform with protection from the Western rain.
- Rain from the West may penetrate the full depth of the Northernmost platform.

[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

- There is a low possibility of rain penetrating the concourse building due to the orientation of the entry way in relation to the prevailing rain directions.

As a benchmark, Green Star Railway Stations 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. This preliminary assessment indicates that this requirement is not being achieved. Consideration should be given to ascertain if this requirement pertains to the peak occupancy rates of Queens Park station.

Solar Access and Control

The level of shade protection from direction sunlight on the nominated planes (platform level and station entry on the ground plane) was assessed at the autumn and spring equinoxes and the summer solstice. This assessment was performed to check if the shading provided protects passengers from extensive sun exposure to ensure an acceptable level of comfort on the platform.

Shading is provided to both platforms by architectural canopy shells which then extends into a horizontal only platform canopy. The concourse and station entry are shaded by its positioning below the rail corridor. Approximately 103.5 m of each platform (70%) is covered by a canopy.

As a benchmark for this analysis, Green Star – Railway Stations 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).

Analysing the altitude and azimuth paths of the sun found:

At 2pm,

- The canopies of both platforms provide some shading from the higher sun angle.
- The Southernmost platform may see solar exposure through the gap between the canopy and 1.5m high platform barrier. However, some shading from the canopy will be provided to edge of the platform adjacent to the rail corridor.
- Both platforms are more likely to see a greater penetration from the Autumn and Spring azimuth angles.
- Preliminary assessments have determined that the Northernmost platform, at 2pm, does not meet the Greenstar minimum 20% of shaded area. However, the Southernmost platform may receive approximately 35% shaded area at this time.

At 6pm,

- The Northernmost platform will likely see the 6pm solar exposure under the canopy.
- As per the 2pm observation, there is potential for solar exposure through the gap between the canopy and the platform barrier of the Southernmost platform.
- However, the canopy shell of the Southernmost platform will likely provide protection to both platforms from the low sun angle.
- Preliminary assessments have determined that the Southernmost platform may satisfy the Greenstar minimum 20% of shaded area at this time. The Northernmost platform is projected to not meet this requirement.

Solar Reflection

Reflectivity glare from new infrastructure in the development has been assessed to indicate areas prone to risk of impacting staff and patrons or glare to train drivers. This assessment only analyses reflectivity glare from new infrastructure in the development. Given its subjective nature, discomfort glare has not been considered.

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 preliminary assessment 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 the any shiny surfaces under the canopy shell of the Southernmost platform to the East, impacting train drivers on both train lines and/or passengers on the Northernmost platform.
- There may also be potential for the sun to shine through and interact with the louvred glass feature of the canopy shell, impacting train drivers on the line travelling to Armadale.

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 the any shiny surfaces under the canopy shell of the Northernmost platform to the West and impact train drivers on both train lines and/or passengers on the Southernmost platform.
- There may also be potential for the sun to shine through and interact with the louvred glass feature of the canopy shell, impacting train drivers on the line travelling to Perth.

Potential methods of mitigating the risk of reflected sunlight from the surfaces highlighted above is to:

- Ensure that the surfaces of elements underneath the canopy shell (eg. walls, decorative panels, pedestrian barriers) have a finish that reduces reflectivity. I.e. surfaces that have a degree of surface roughness (to scatter light) instead of smooth / gloss finishes.
- Ensure that glazing has have low reflective films applied that reduce the amount of light reflected form the surface. This will require verification from the glazing manufacturer.

Further analysis would be required to determine the minimum reflectivity required to maintain acceptable reflected light levels based on the angles from the train driver's and passengers' view.

Natural Light

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.

It is recommended that as the design progresses, natural light in frequently occupied internal spaces is assessed. 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.

ARMADALE LINE UPGRADE ALLIANCE

Notice of Advice

Attention	John-Paul Davies		
Company	Hassell Studio	Date	21-Dec-2022
CC	Mimi Cho James Brougham Ben Hoy	Total Page	21
Project Name	ALXR Detailed Design - Queens Park V2	Project No.	60676692
AECOM Ref	60676692		
From	Laura Donaldson and Steph Liu		
Service	Environmental Comfort		

1.0 Introduction

The purpose of the following Notice of Advice (NOA) is to summarise previous Environmental Comfort desktop studies and highlight any potential areas where the requirements from the Scope of Works and Technical Criteria (SWTC) (relevant clauses referred to in Table 2) may not be met for the Queens Park Station design in advance of the final model freeze and Final Detailed Design (FDD). deadlines.

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 NOA 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.

A final report will be prepared for Queens Park one week before the FDD Report deadline summarising the outcomes of the environmental comfort assessment using drawings and the BIM360 after the final model freeze.

2.0 Data Summary

Historic weather data has been used to complete the Environmental Comfort Assessments. Weather data from Perth Metro and Jandakot weather stations was obtained from the Bureau of Meteorology for the analysis. The data from the weather station closest to each station was used in the assessments.

The data obtained considers average wind speeds and direction and rainfall at short intervals. It does not consider wind gusts.

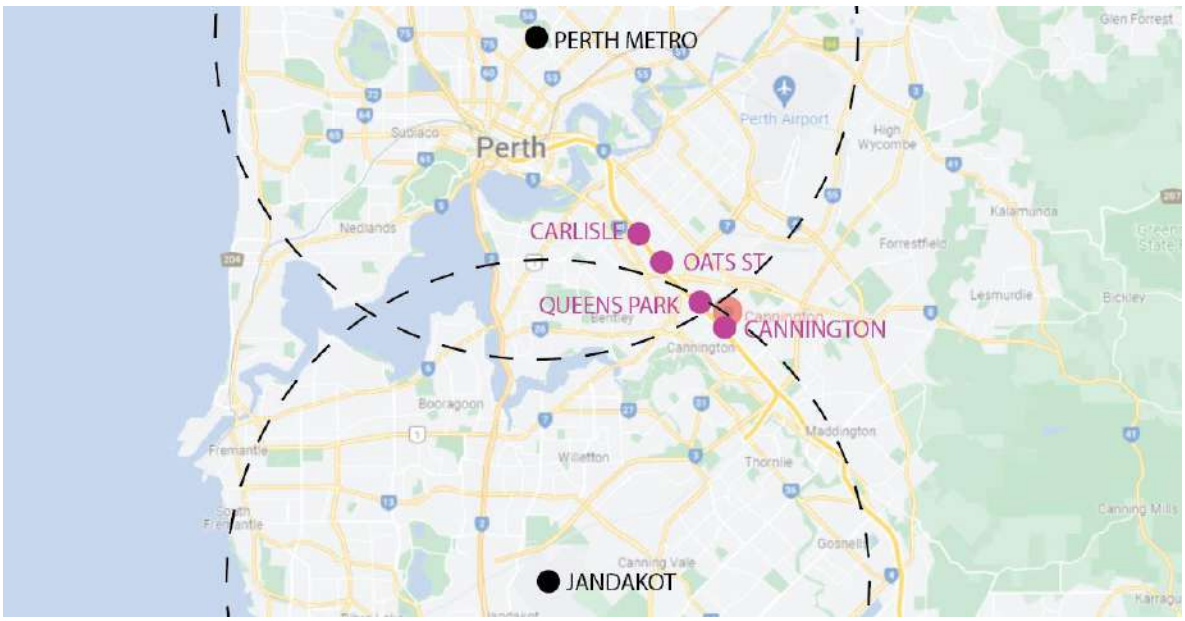


Figure 1: Weather Station Locations

2.1 Rain

Refer to section 4.0 for further details. Weather data was obtained to understand the prevailing wind directions during rain events to understand the impacts of wind driven rain. Note that past weather data demonstrates that at Perth Metro it rains for 6% of the year and at Jandakot it rains for 7% of the year. The most common wind driven rain direction in both locations is from the West.

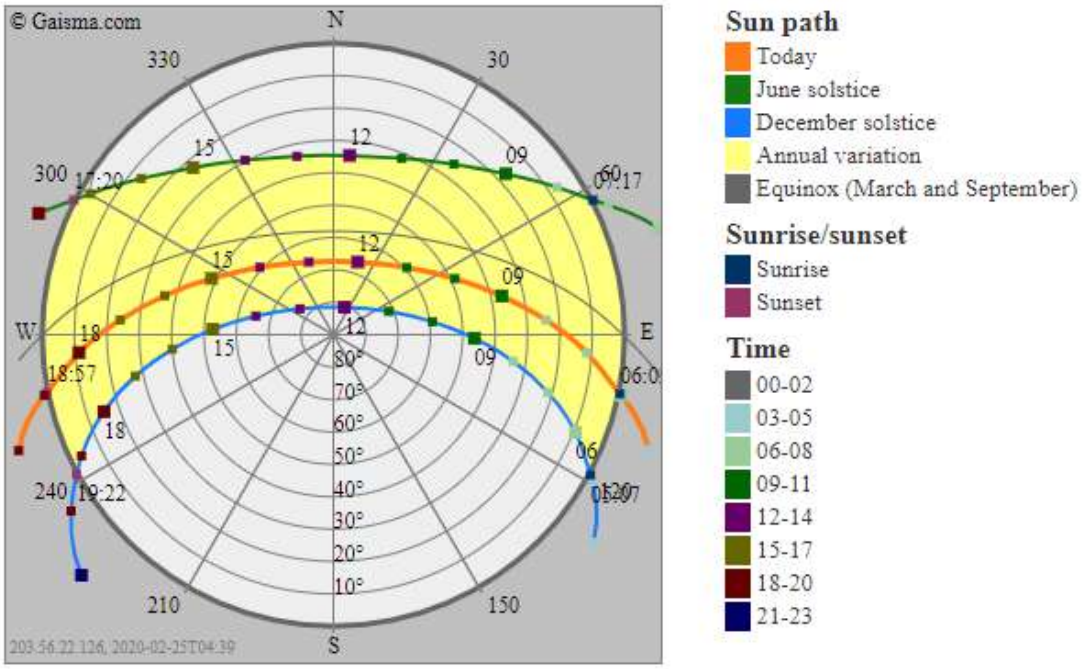
2.2 Wind

Refer to section 4.0 for further details. Weather data was obtained to understand the prevailing wind directions. The three prevailing wind directions are typically from the East, South and Southwest.

2.3 Solar Exposure

Figure 2 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 moves from East to West across each day, 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 2 Perth Sun Path Diagram



2.4 Climate Change

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. The Queens Park Station is located in the Southern and South-Western Flatlands West sub cluster.

Climate change projections for the Queens Park Station location indicate that average 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.

3.0 Environmental Comfort Assessment

A high-level environmental comfort study has been completed to assess solar access and control, natural lighting, solar reflection, rain protection and wind protection for commuter comfort. The assessments provide a high-level overview of the potential impacts the station designs have on patron comfort due to environmental factors. They do not consider safety 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.

As per the Green Star Assessment and Strategy Report (prepared September 2022), Queens Park is not targeting a formal Green Star rating and is therefore not required to meet the requirements of the rating tool. Additionally, this NOA is not intended to represent the Green Star credit submission should a formal rating be pursued.

The following assessments were completed during the Reference Design Stage:

Wind comfort study:

The assessments look at prevailing winds and average wind speeds at each station location. To determine whether the prevailing winds would cause discomfort for passengers at the station, the

Lawson comfort criteria[1] has been used. The criteria is based on the probability of exceeding certain mean wind speeds. Wind conditions are unacceptable when the probability of the mean wind speed exceeding the given number is greater than 5%.

Table 1: 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

The assessment is completed using average wind speeds and directions to analyse the comfort conditions of passengers. It does not consider safety risks such as wind gusts or wind tunnelling.

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.

Rain comfort study:

The assessments looked at prevailing wind speeds and directions when it is raining to provide advice on probable rainfall angles and its impact on waiting passengers.

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 is defined as stations where morning and afternoon commuting passengers regularly fill the platform. However, as identified above, 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 NOA 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

Solar access and control:

The assessments analyse how shaded the nominated plane (platform level) is from direct sunlight at autumn and spring equinoxes and the summer solstice. The assessments are performed to check if the shading provided protects passengers from extensive sun exposure to ensure 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).

Glare/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 new infrastructure in the development. The assessments do not consider safety or human comfort.

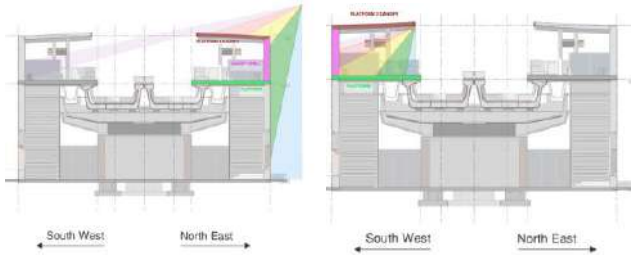
Refer to previous desktop studies and Project Definition Report (PDR) for details on the assessments completed.

[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

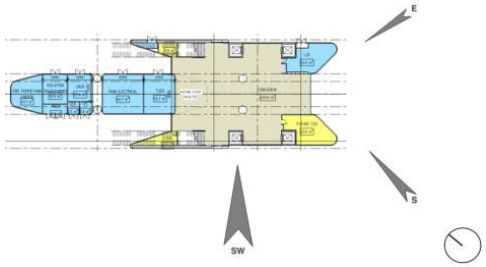
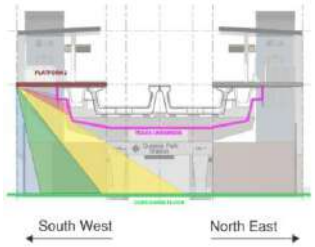
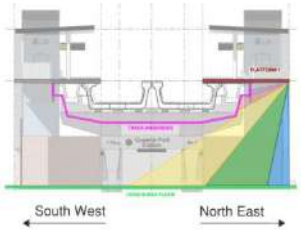
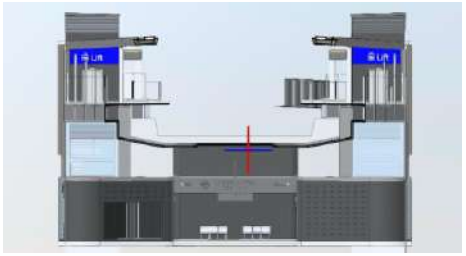
3.1 Environmental Comfort Summary

Table 2 below outlines the outcomes of the Environmental Comfort Assessment against each of the relevant criteria from the SWTC. The below table summarises previous desktop studies and PDR inputs and compares the assessments with the most recent model (accessed during the week beginning 12/12/22). Key changes or areas of concern are highlighted.

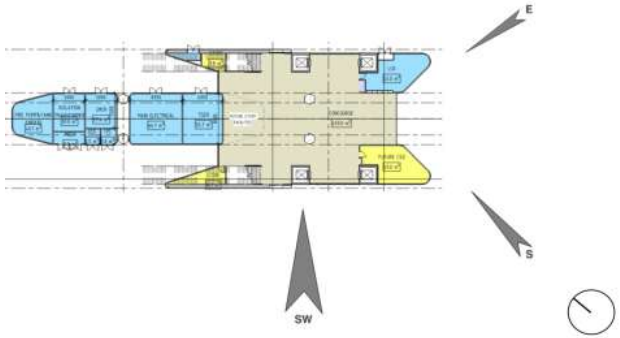
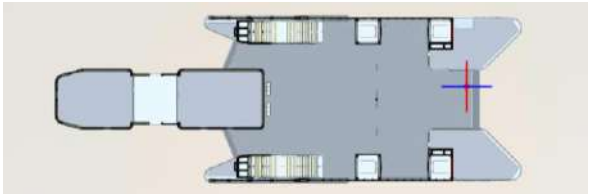
Table 2: SWTC Environmental Comfort Scope Items

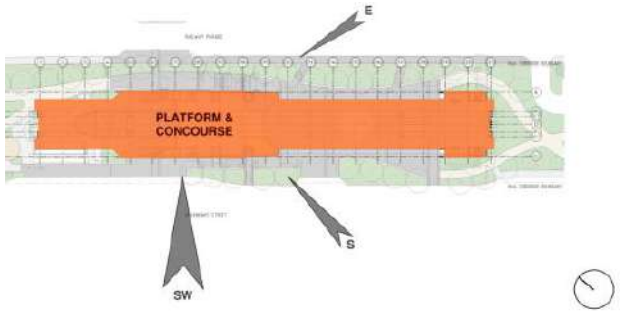
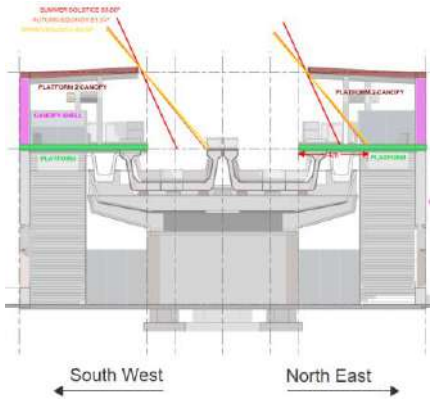
#	Scope Item	Applicable Areas / Studies	Desktop Study and PDR Summary (Reference Design)	Comments
22.1 Station Precinct, Station Buildings and Facilities General Requirements				
01	22.1-19: Platform Roofing: The NOP shall review provision of additional screening to mitigate potential for rain to encroach 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	**West Rain**  **North Rain** 	Minimal changes to section and canopy design which are not anticipated to have a substantial effect on previous assessment results/outcomes.  Depending on the rain speed and rain angle, there is the potential for rain to penetrate the full depth of each platform (i.e., yellow, red and purple rain angles). These rain angles are representative of rain falling in these zones for less than 6% of the year from the west and less than 4% of the year from the north.
02		Pedestrian stairs	Refer to above platform diagrams (#01).	The pedestrian stairs have a similar cross section to that of the pedestrian safe zone. However, elements of the canopy screening will have perforations adjacent to the stairs. This is anticipated to provide some protection to the stairs but will not fully restrict rain from entering.

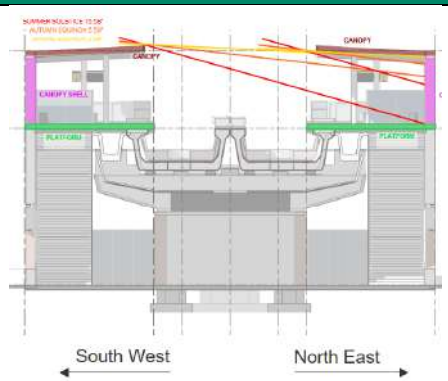
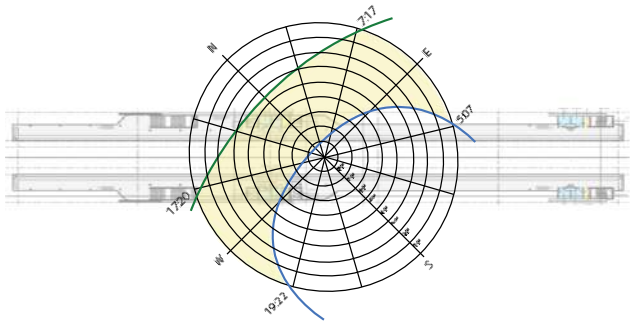
#	Scope Item	Applicable Areas / Studies	Desktop Study and PDR Summary (Reference Design)	Comments
				 Therefore, both platforms will be impacted by rainfall on the stairs. However, the rain will be minimised by the perforated screening. Note that environmental comfort studies assess general conditions and cannot evaluate the screening's specific effects.
03		Future escalators	N/A. No future escalators anticipated.	
04		Lift zones	Refer to above platform diagrams (#01).	The lift zones have a similar cross section to that of the pedestrian safe zone.  Depending on the rain speed and rain angle, there is the potential for rain to penetrate the full depth of each platform (i.e., yellow, red and purple rain angles). These rain angles are representative rain falling in these zones for less than 6% of

#	Scope Item	Applicable Areas / Studies	Desktop Study and PDR Summary (Reference Design)	Comments
				the year from the west and less than 4% of the year from the north.
05	22.1-197 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); and	Station entry(s)	**Prevailing Winds**  **West Rain**  **North Rain** 	Minimal changes to section and canopy design which are not anticipated to have a substantial effect on previous assessment results/outcomes.  **Wind:** The diagram to the left demonstrates how the prevailing wind directions may affect the concourse station entrance. The station entry could see crosswind from the Southwest prevailing wind, as well as the potential for the East and Southern winds to penetrate the station entry. However, typically the wind from each of these directions are at a comfortable speed, in accordance with the Lawson comfort criteria. **Rain:** The concourse entry in this design has the cover of the overhead platform and tracks denoted by the brown and pink in the reference design markups respectively. Rain from the West direction will most likely fall at the green and yellow rain angles (occurring approximately 5% of the year), which could possibly impact the external area just prior

#	Scope Item	Applicable Areas / Studies	Desktop Study and PDR Summary (Reference Design)	Comments
				to the station entry. Rain from the West is unlikely to penetrate the station entry. Rain from the North direction will most likely fall at the green and blue rain angles (occurring approximately 5% of the year) this could possibly impact the concourse floor just prior to the station entry. Rain from the North is unlikely to penetrate the station entry.
06		Station foyer(s)	Refer to diagrams above (#05).	As identified above, there is potential for prevailing winds to enter the station foyer, however they are typically at comfortable speeds. The station foyer is well protection from wind driven rain from the prevailing directions of North and West.
07	22.1-197 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	Refer # 02 above.	
08		Fare gates	Refer to diagrams above (#05).	As identified above, there is potential for prevailing winds to enter the station foyer, however they are typically at comfortable speeds. The station foyer (and therefore fare gates) is well protected from wind driven rain from the prevailing directions from the North and West.
09		Ticketing machines	Refer to diagrams above (#05).	As identified above, there is potential for prevailing winds to enter the station foyer, however they are typically at comfortable speeds. The station foyer (and therefore ticketing machines located within the foyer) is well protected from wind driven rain from the prevailing directions from the North and West.

#	Scope Item	Applicable Areas / Studies	Desktop Study and PDR Summary (Reference Design)	Comments
10		Dedicated platform safe zones	Refer # 01 above.	
22.4.3/22.4.5 Reference/ Detailed Design				
11	22.4.3-3-19 (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		Minimal changes to section and canopy design which are not anticipated to have a substantial effect on previous assessment results/outcomes.  The diagram to the left demonstrates how the prevailing wind directions may affect the concourse station entrance. The station entry could see crosswind from the Southwest prevailing wind, as well as the potential for the East and Southern winds to penetrate the station entry. However, typically the wind from each of these directions are at a comfortable speed, in accordance with the Lawson comfort criteria.

#	Scope Item	Applicable Areas / Studies	Desktop Study and PDR Summary (Reference Design)	Comments
12		Platforms		The diagram to the left indicates that the sections of platform that extend beyond the cover of the canopy shell are relatively exposed for each of the prevailing wind directions. The wind from the South directions at the platform height of 9.5m is considered comfortable for short periods of time according to the Lawson comfort criteria. However, more than 30% of the wind from the East direction, and more than 45% of the wind from the South-West direction could reach uncomfortable speeds for occupants (equal to speeds greater than 6m/s). Some protection may be available by the platform canopy shell where the canopy shell is not permeable. The two canopy shells appear to provide considerable protection from prevailing winds to the sections of the platforms that they envelope (i.e. safe zones).
13	22.4.3-3-22 (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.	Solar access and control	**2pm Altitude**  **6pm Altitude**	At 2pm: • The canopies of both platforms provide some shading from the higher sun altitude. • The Southernmost platform is completely protected where there is no glazing, or perforations in the canopy shell. • The Northernmost platform is more likely to see a greater penetration of solar radiation from the Autumn and Spring azimuth angles. • Preliminary assessments have determined that the Southernmost platform will satisfy the Green Star requirements for a minimum 20% of shaded area at 2pm. The Northernmost platform is projected to not meet this requirement however there will be some areas of protection. At 6pm:

#	Scope Item	Applicable Areas / Studies	Desktop Study and PDR Summary (Reference Design)	Comments
				• The Northernmost platform will likely see the 6pm solar exposure penetrate under the canopy. • As per the 2pm observation, the Southernmost platform is completely protected where there is no glazing or perforations in the canopy shell. • Preliminary assessments have determined that the Southernmost platform will satisfy the Green Star requirements for a minimum 20% of shaded area at 6pm. The Northernmost platform is projected to not meet this requirement.
14		Wind	Refer to #11 and #12 above.	
15		Rain protection	Refer to #01 to #06 above.	
16		Solar Reflection		The preliminary assessment 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 Southernmost platform to the East, impacting train drivers on both train lines and/or passengers on the Northernmost 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 Northernmost platform to the West and impact train drivers on both train lines and/or passengers on the Southernmost platform.

#	Scope Item	Applicable Areas / Studies	Desktop Study and PDR Summary (Reference Design)	Comments
				Potential methods of mitigating the risk of reflected sunlight from the surfaces highlighted above is to: • Ensure that the surfaces of elements underneath the canopy shell (e.g. walls, decorative panels, pedestrian barriers) have a finish that reduces reflectivity. I.e. surfaces that have a degree of surface roughness (to scatter light) instead of smooth / gloss finishes. • Ensure that glazing has low reflective films applied that reduce the amount of light reflected form the surface. This will require verification from the glazing manufacturer. Further analysis would be required to determine the minimum reflectivity required to maintain acceptable reflected light levels based on the angles from the train drivers' and passengers' view.
17		Natural Light	N/A. Queens Park is an un-staffed station and therefore has no internal spaces intended to be occupied for extended periods of time requiring daylight. Approach confirmed with PTA on 15/12/2022.	

4.0 Weather Data

Table 3 below summarises the outputs from the historical weather data obtained for rain, wind and solar exposure at both Perth Metro and Jandakot weather stations.

Table 3: Environmental Comfort Data

<table>
<tr><th>Assessment</th><th>Perth Metro</th><th>Jandakot</th></tr>
<tr><td>Rain</td><td>
In Perth Metro, the mean annual rainfall is 736.8mm and it rains for 6% of the year.

The tables below show the times of year and the time of day when this rain is likely to occur. 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

Frequency of Rainfall Based on Season
<table>
<tr><th>Period</th><th>Months</th><th>Occurrence</th></tr>
<tr><td>Summer</td><td>Dec - Feb</td><td>7%</td></tr>
<tr><td>Autumn</td><td>Mar - May</td><td>21%</td></tr>
<tr><td>Winter</td><td>Jun - Aug</td><td>52%</td></tr>
<tr><td>Spring</td><td>Sep - Nov</td><td>19%</td></tr>
</table>
Frequency of Rainfall Based on Season
<table>
<tr><th>Period</th><th>Time</th><th>Occurrence</th></tr>
<tr><td>Night</td><td>0:00 - 06:00</td><td>27%</td></tr>
<tr><td>Morning</td><td>06:00 - 12:00</td><td>24%</td></tr>
<tr><td>Afternoon</td><td>12:00 - 18:00</td><td>24%</td></tr>
<tr><td>Evening</td><td>18:00 - 24:00</td><td>25%</td></tr>
</table>
</td><td>
In Jandakot, the mean annual rainfall is 818.4mm and it rains for 7% of the year.

The tables below show the times of year and the time of day when this rain is 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

Frequency of Rainfall Based on Season
<table>
<tr><th>Period</th><th>Months</th><th>Occurrence</th></tr>
<tr><td>Summer</td><td>Dec - Feb</td><td>7%</td></tr>
<tr><td>Autumn</td><td>Mar - May</td><td>20%</td></tr>
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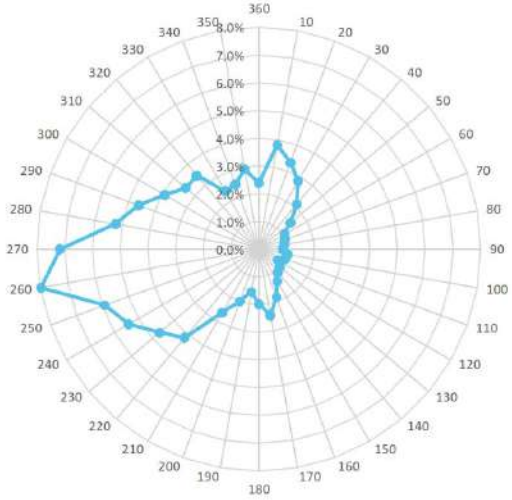
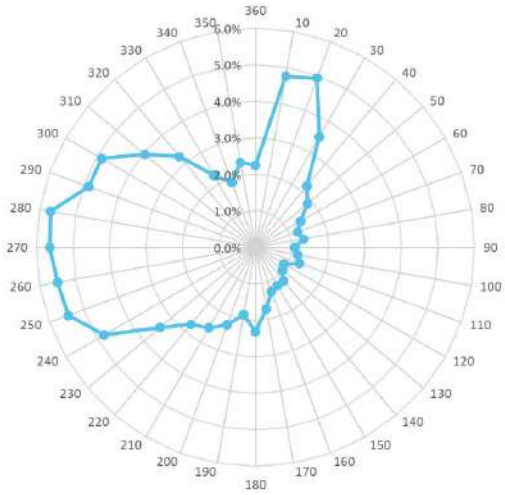
<tr><td>Afternoon</td><td>12:00 - 18:00</td><td>23%</td></tr>
<tr><td>Evening</td><td>18:00 - 24:00</td><td>26%</td></tr>
</table>
</td></tr>
</table>

Assessment	Perth Metro	Jandakot
	To consider the angle that rain may fall, the wind direction is taken into account. As per the weather data obtained from Perth Metro weather station, when rain is falling, there is broadly one prevailing wind direction as shown in Figure 3 below: • West (220° to 300°) accounting for 49.1% of the annual hours when precipitation occurs  **Figure 3: Perth Metro Wind Rose (when rain is occurring)** **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):	To consider the angle that rain may fall, the wind direction is taken into account. As per the weather data obtained from Jandakot weather station, when rain is falling, there are broadly two prevailing wind directions as per Figure 4 below: • 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 4: Jandakot Wind Rose (when rain is occurring)** **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):

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) – 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%	• 0° to 11° - less than 1% • 11° to 17° (purple) – less than 1% • 17° to 28° (red) – 9.5% • 28° to 50° (yellow) – 37.2% • 50° to 78° (green) – 38.4% • 78° to 90° (blue) – 13.9%

Considering past data shows it rains for 6% of the year, the above percentages could translate to the following percentages across the year. Note that these numbers are provided as a guide only as the 6% of the year is inclusive of rain at all directions whereas the above is inclusive of the Western rain only. The approach and percentages below are therefore a conservative representation.:

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) – less than 1% • 28° to 50° (yellow) – less than 1% • 50° to 78° (green) – 3.6% • 78° to 90° (blue) – 1.7%	• 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) – 2.2% • 50° to 78° (green) – 2.3% • 78° to 90° (blue) – less than 1%

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, the above percentages could translate to the following percentages across the year. Note that these numbers are provided as a guide only as the 7% of the year is inclusive of rain at all directions whereas the above is inclusive of the Western rain only. The approach and percentages below are therefore a conservative representation.

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%

Northern Rain:

When rain is occurring, rain from the northern direction is likely to fall from the following angles at 1 metre and 8 metres high:

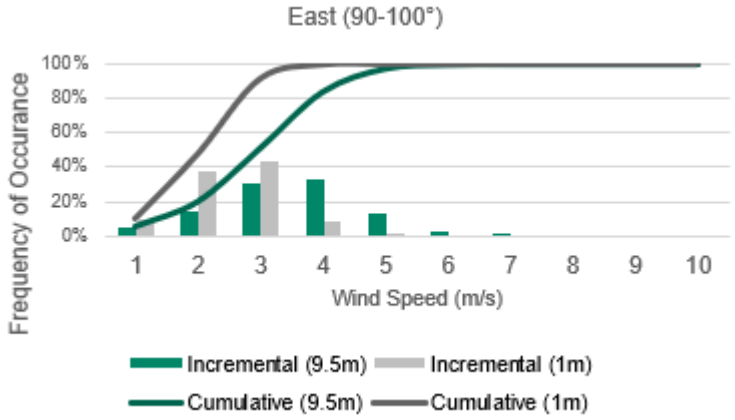
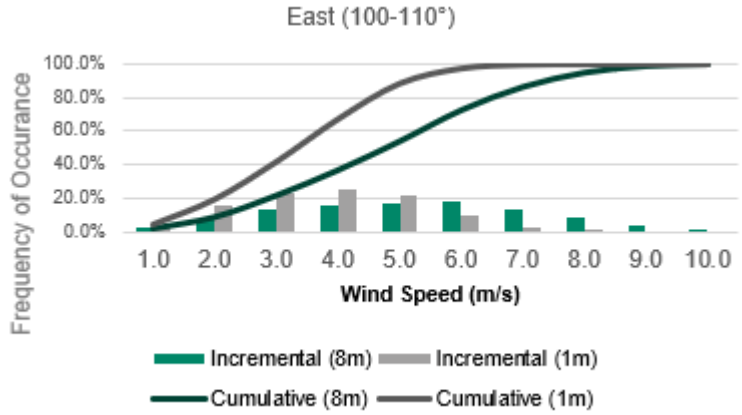
Northern Rain Frequency at 1m and 9.5m (When Raining)

<table>
<tr><th>Assessment</th><th>Perth Metro</th><th>Jandakot</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><th>1 metre (ground level)</th><th>9.5 metres above ground level (approximate platform height)</th></tr>
<tr><td>• 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%</td><td>• 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%</td></tr>
</table>
Considering past data shows it rains for 7% of the year, the above percentages could translate to the following percentages across the year. Note that these numbers are provided as a guide only as the 7% of the year is inclusive of rain at all directions whereas the above is inclusive of the Northern rain only. The approach and percentages below are therefore a conservative representation.

Northern Rain Frequency at 1m and 9.5m (Across Year)
<table>
<tr><th>1 metre (ground level)</th><th>9.5 metres above ground level (approximate platform height)</th></tr>
<tr><td>• 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%</td><td>• 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%</td></tr>
</table>
</td></tr>
<tr><td>Wind</td><td>The analysis determined that there are three prevailing wind directions at Perth Metro:

• East (90° to 100°) accounting for 8.7% of the year
• South (170°) accounting for 5.8% of the year
• Southwest (210° to 220°) accounting for 12.7% of the year</td><td>The analysis determined that there are three prevailing wind directions at Jandakot:

• 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</td></tr>
</table>

Assessment	Perth Metro	Jandakot
	The Lawson[2] comfort criteria has been used in this assessment. The criteria is 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. The windspeeds experienced at the 9.5m height of the platforms is considerably faster than the speeds seen at ground level. The height comparison is demonstrated, for each prevailing direction, in the diagrams below.  **Figure 5 Wind speed comparison at heights of 1m and 9.5m (East wind)**	The Lawson[3] comfort criteria has been used in this assessment. The criteria is 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. The windspeeds experienced at the 8m height of the platforms is considerably faster than the speeds seen at ground level. The height comparison is demonstrated, for each prevailing direction, in the diagrams below.  **Figure 8 Wind speed comparison at heights of 1m and 8m (East wind)**

[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

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

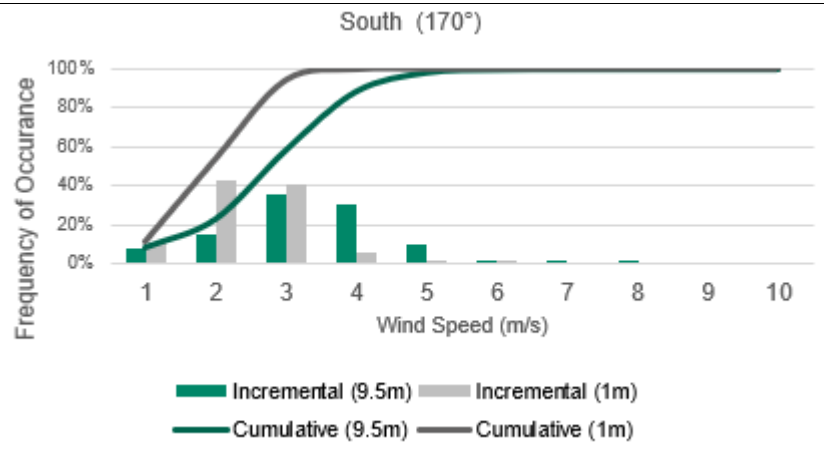


Figure 6 Wind speed comparison at heights of 1m and 9.5m (South wind)

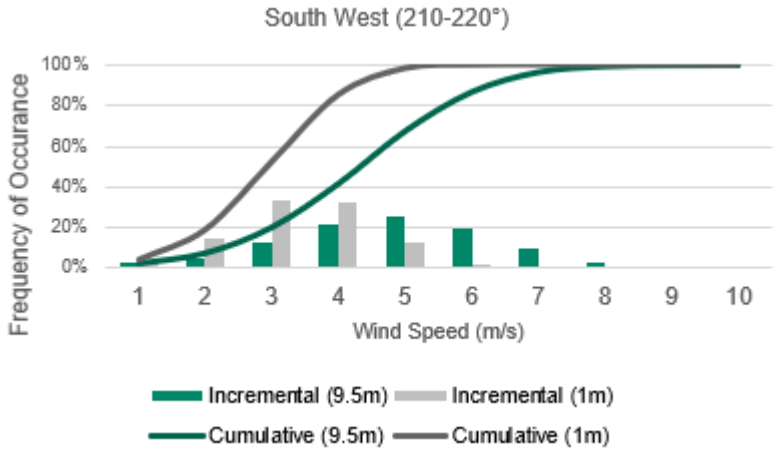


Figure 7 Wind speed comparison at heights of 1m and 9.5m (Southwest wind)

At ground level:

- All wind from the Eastern direction (100%) has a speed of 6m/s or less.

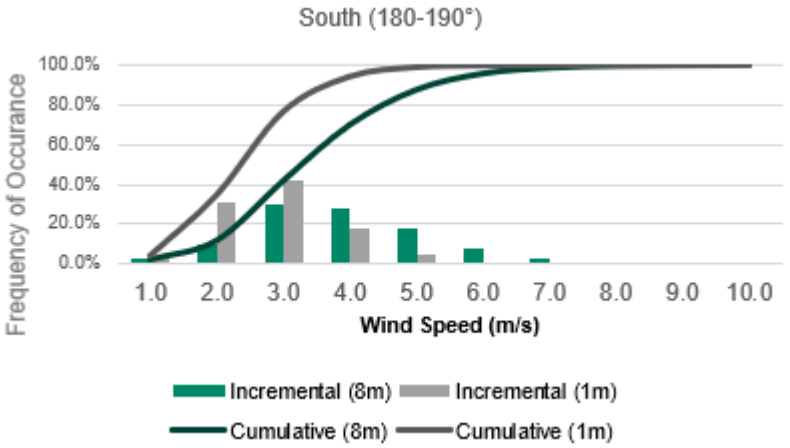


Figure 9 Wind speed comparison at heights of 1m and 8m (South wind)

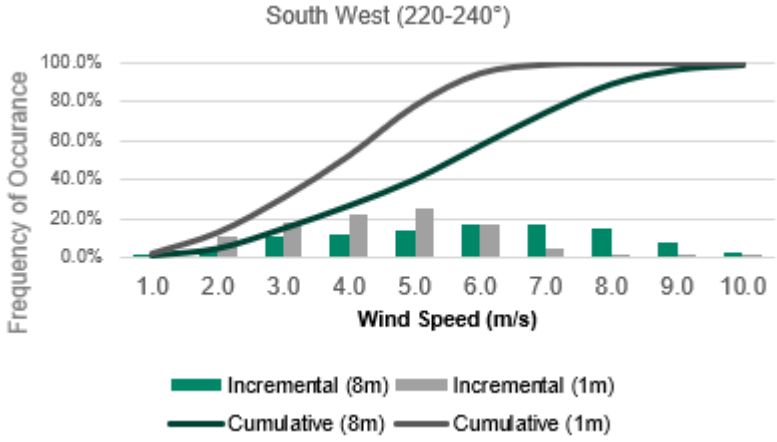


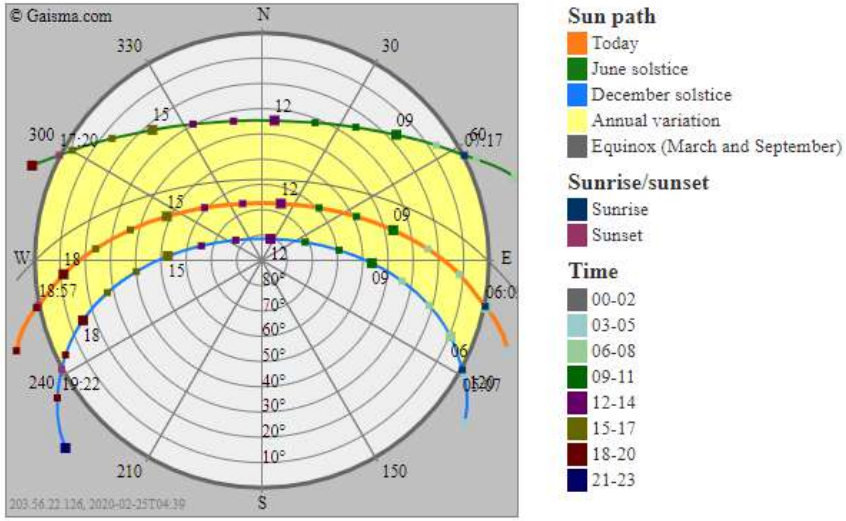
Figure 10 Wind speed comparison at heights of 1m and 8m (Southwest wind)

At ground level:

- The majority of wind from the Eastern direction (97.5%) has a speed of 6m/s or less.

Assessment	Perth Metro	Jandakot
	• All wind from the Southern direction (100%) has a speed of 6m/s or less. • The majority of wind from the Southwestern direction (99%) has a speed of 6m/s or less. Each of the prevailing wind directions are considered comfortable for passengers sitting or standing for short periods of time under the Lawson comfort criteria. At platform level: • The great majority of wind from the Eastern direction (99.8%) has a speed of 6m/s or less. • The great majority of wind from the Southern direction (99.8%) has a speed of 6m/s or less. • A notable distribution of wind from the Southwestern direction (32%) has a speed of 6m/s or above. A considerable proportion of the Southwest directions are considered uncomfortable for passengers sitting or standing for short periods of time under the Lawson comfort criteria.	• The majority of wind from the Southern direction (99.5%) has a speed of 6m/s or less. • The majority of wind from the Southwestern direction (95%) has a speed of 6m/s or less. Each of the prevailing wind directions are considered comfortable for passengers sitting or standing for short periods of time under the Lawson comfort criteria. At platform level: • A greater frequency of wind from the Eastern direction (46.1%) has a speed of 6m/s or above. • A greater frequency of wind from the Southern direction (12.4%) has a speed of 6m/s or above. • The majority of wind from the Southwestern direction (59.7%) has a speed of 6m/s or above. A high proportion of the Southwest and East wind directions are considered uncomfortable for passengers sitting or standing for short periods of time under the Lawson comfort criteria.
Solar Exposure and Glare	Figure 2 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 moves from East to West across the day, 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.	

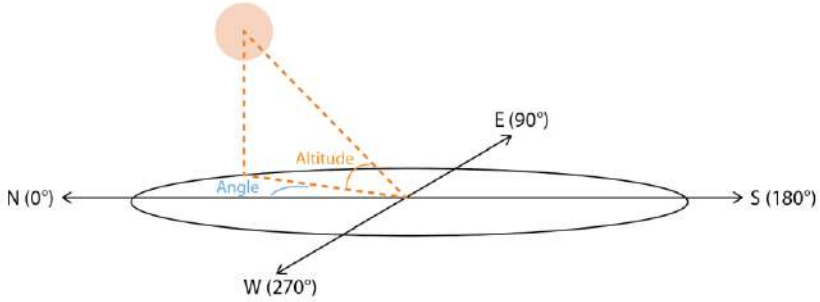
Figure 11 Perth Sun Path Diagram



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 12 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 shining from, whereas the sun altitude refers to the angle of the sun relative to the earth's horizon.

Figure 12 Definition of sun angle and altitude



Assessment	Perth Metro	Jandakot

The table 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.

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

ARMADALE LINE UPGRADE ALLIANCE

Appendix B
PTA MEETING MINUTES

Environmental Comfort

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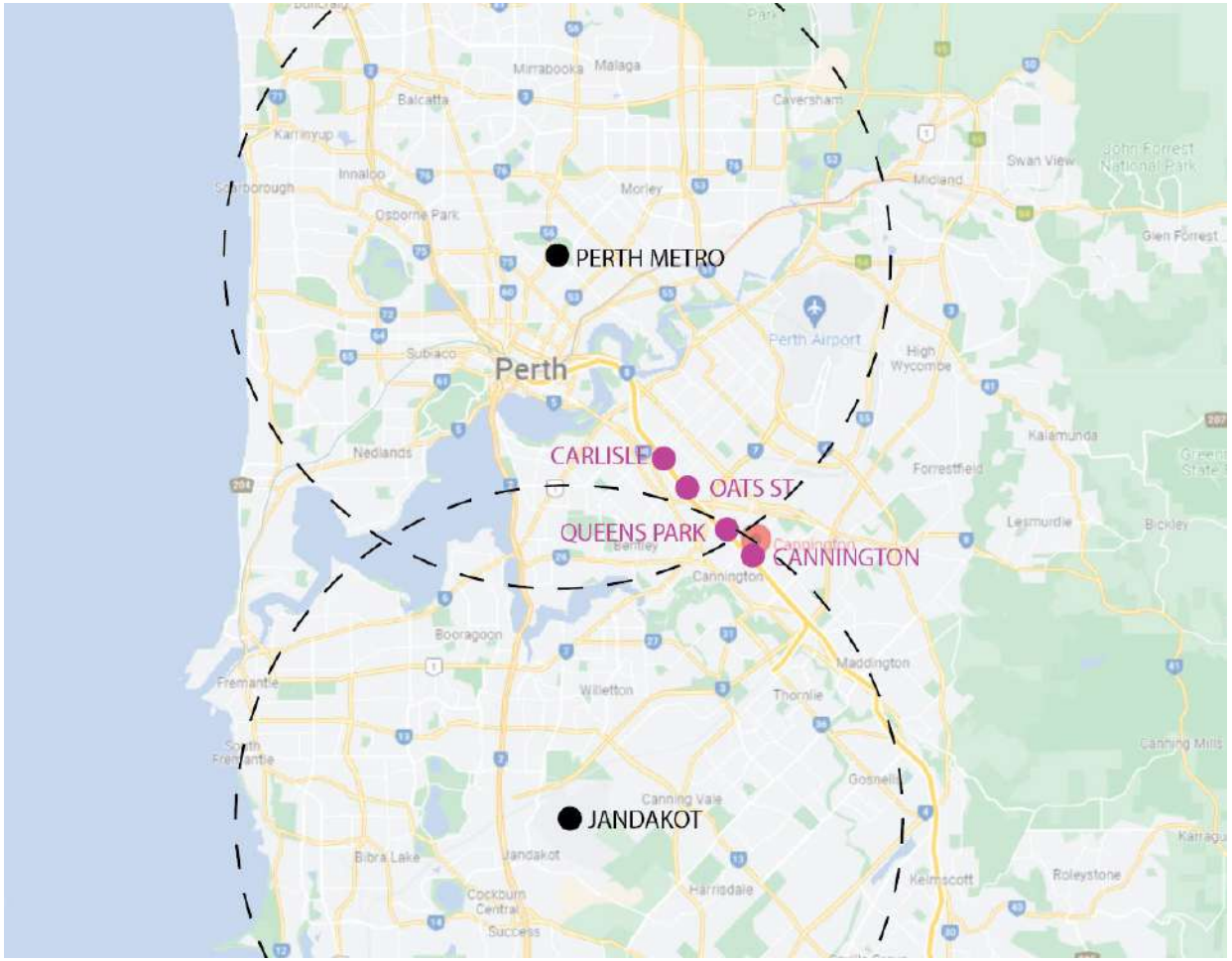
Weather Data

Based on past weather data (i.e. experienced data)



Rain Weather Data (past climate data)

JANDAKOT

- Mean annual rainfall is 818.4mm
- Raining 7% of year
- Frequency of rainfall (season)

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

- Frequency of rainfall (time of 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%

PERTH METRO

- Mean annual rainfall is 736.8mm
- Raining 6% of year
- Frequency of rainfall (season)

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

- Frequency of rainfall (time of day)

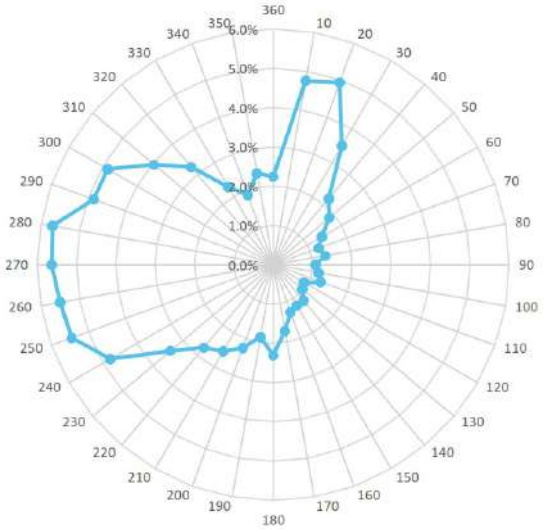
Period	Time	Occurrence
Night	0:00 - 06:00	27%
Morning	06:00 - 12:00	24%
Afternoon	12:00 - 18:00	24%
Evening	18:00 - 24:00	25%

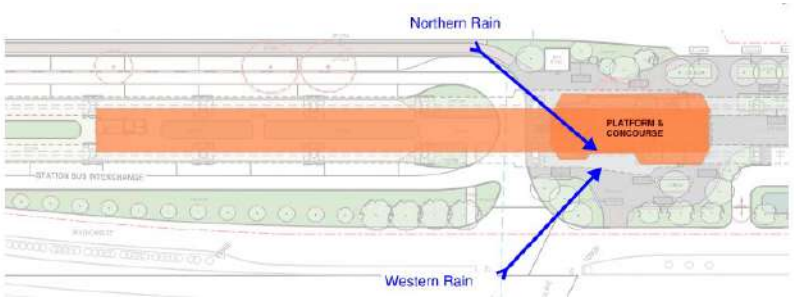
Note that climate projections indicate that annual mean rainfall is likely to decrease, however the intensity is likely to increase.

Rain Weather Data (past climate data)

JANDAKOT

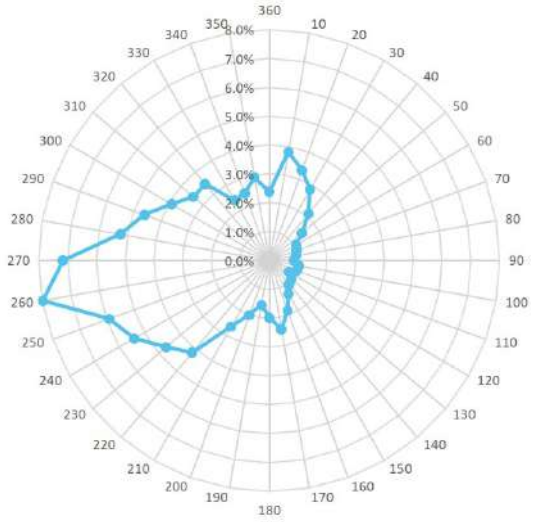
- Rain Direction
  - West (240° to 300°) accounting for **36.8%** of the annual hours when precipitation occurs
  - North (10° to 20°) accounting for 9.7% of the annual hours when precipitation occurs

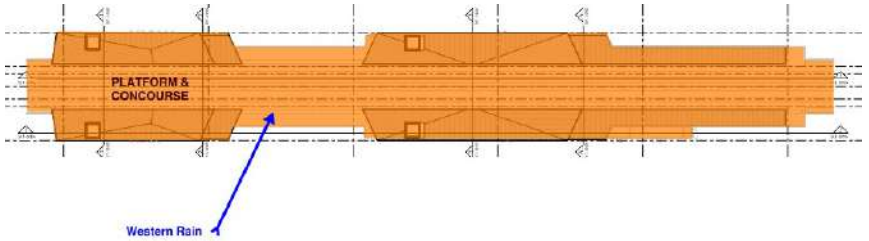




PERTH METRO

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





Rain Weather Data (past climate data)

JANDAKOT

Western Rain

1 metre (ground level)	8 metres above ground level (approximate platform height)
• 0° to 11° - less than 1%	• 0° to 11° (grey) - less than 8.1%
• 11° to 17° (purple) – 2.2%	• 11° to 17° (purple) – 19%
• 17° to 28° (red) – 17.4%	• 17° to 28° (red) – 26.2%
• 28° to 50° (yellow) – 37.6%	• 28° to 50° (yellow) – 26.5%
• 50° to 78° (green) – 32.9%	• 50° to 78° (green) – 15.9%
• 78° to 90° (blue) – 9.7%	• 78° to 90° (blue) – 4.2%

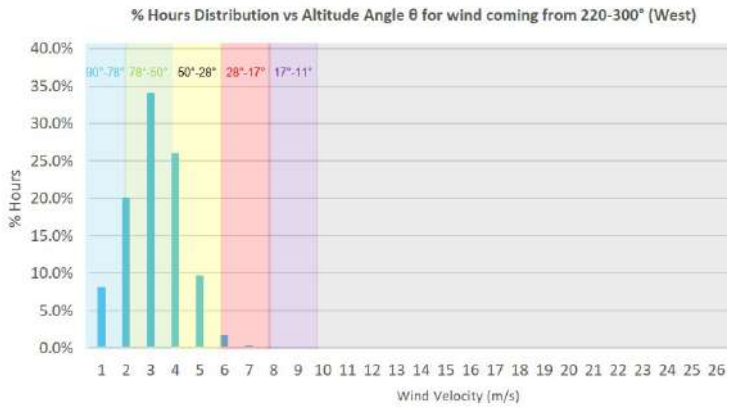
Northern Rain

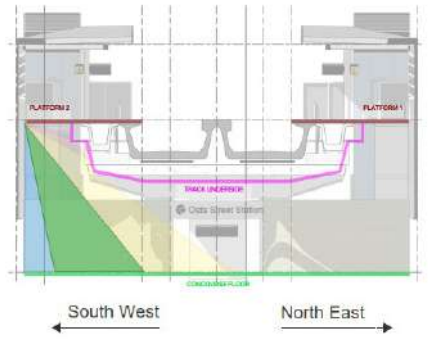
1 metre above ground level	8 metres above ground level
• 0° to 11° - less than 1%	• 0° to 11° - less than 1.7%
• 11° to 17° (purple) – 1.1%	• 11° to 17° (purple) – 4.0%
• 17° to 28° (red) – 3.1%	• 17° to 28° (red) – 9.2%
• 28° to 50° (yellow) – 13.4%	• 28° to 50° (yellow) – 32.8%
• 50° to 78° (green) – 60.4%	• 50° to 78° (green) – 43.6%
• 78° to 90° (blue) – 21.9%	• 78° to 90° (blue) – 8.7%

PERTH METRO

Western Rain

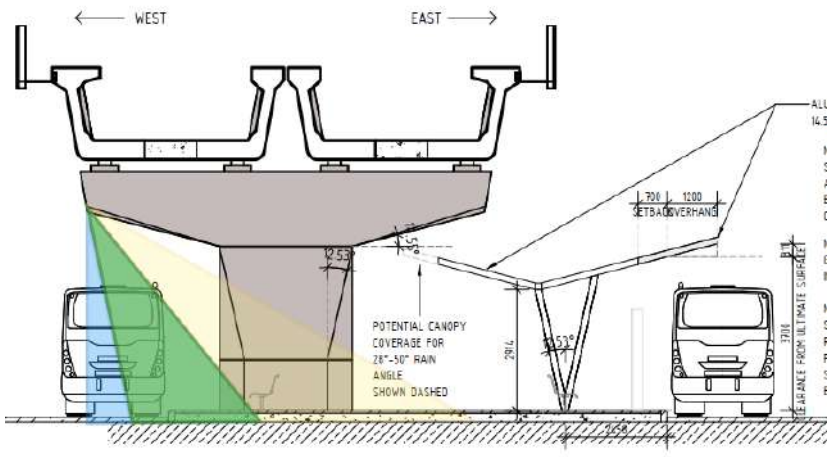
1 metre (ground level)	9.5 metres above ground level (approximate platform height)
• 0° to 11° - less than 1%	• 0° to 11° - less than 1%
• 11° to 17° (purple) – less than 1%	• 11° to 17° (purple) – less than 1%
• 17° to 28° (red) – less than 1%	• 17° to 28° (red) – 9.5%
• 28° to 50° (yellow) – 11.4%	• 28° to 50° (yellow) – 37.2%
• 50° to 78° (green) – 60.1%	• 50° to 78° (green) – 38.4%
• 78° to 90° (blue) – 28.2%	• 78° to 90° (blue) – 13.9%





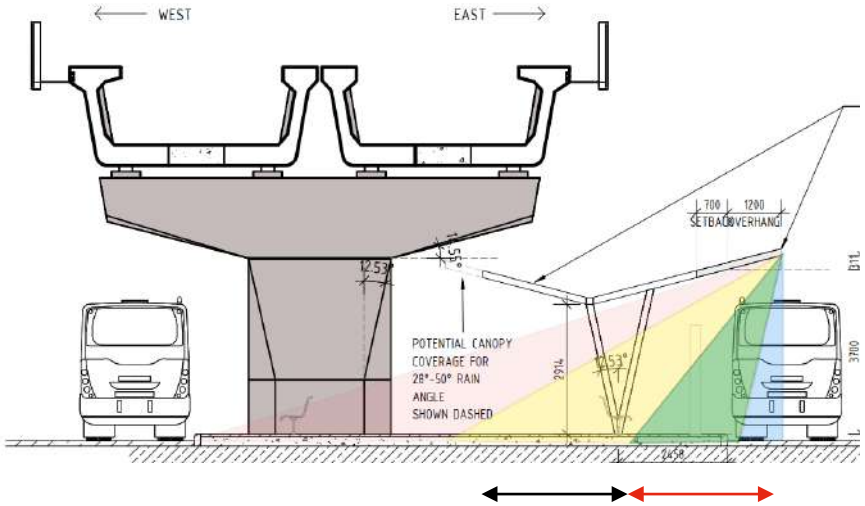
Bus Shelters

Western Rain



- Well protected from western rain

Northern Rain



- Portion of bus shelter will be impacted for 80% of the time when it is raining (green and blue)
- Remainder will be protected for 80% of the time when it is raining

From:	Mimi Cho
To:	Sim, Frederick; Kalantary, Shahpoor; John-Paul Davies; Archie Temelcos; Shortt, Mervyn; Longville, Ian; Hannah Galloway; Ian Stanger; Vidovich, Jake; Temelcos, Archie; Ben Hoy; Jens Wurster; Sean Fong; Adarash Dhar; Iain Roy; chris.evans@alualliance.com.au
Cc:	Moran, Steven; Bilyk, Konstantin; Asokan,Harish; Ben Johnston
Subject:	RE: LXR Detailed Design Sessions 15/12 (Teams Only)
Date:	Thursday, 15 December 2022 6:03:00 PM

Hi All, my notes from this morning below. Feel free to add/amend.

1. **Urban Design update**
    - Queens Park car park relocation
        - coordination has commenced.
        - Presented to CoC – noted as positive change. Potential opportunities for artwork and material variety.
        - SK commented to consider PTA/LGA responsibility of area marked ‘basin’. HG&JP noted this is a shallow area – not typical basin.
    - Queens Park Fire Pumps/Tanks and Public Toilets
        - HG&JP reviewing locations in consideration of future Fast Rail.
        - SK suggested reconsideration of proposed concrete tanks – not easy to maintain.
    - Noise Walls and Retaining Walls
        - Types A, B and C presented.
        - SK suggested encouraging as much urban art as possible to deter graffiti.
        - Both wall and fence are not required – consider access to maintenance items.
2. **Queens Park canopy reduction**
    - JP&MC to review absolute minimum distance allowable from EST mast. Preference is to maximise canopy north.
    - SK suggested extended the canopy to the south to avoid an SWTC Change Request.
    - SK noted a Vicinity Form is required to work 1m from OLE.
    - EST platform lighting is along the viaduct screen as no LV is permitted within 3m from OLE/HV. Maintenance strategy will require workers to use task light or power outlet for supplementary lighting. This strategy was agreed acceptable – no work at night. MS suggested refer Gosnells as a precedent.
3. **Queens Park Store Room at concourse level**
    - TTO miscellaneous storage (eg. Paper, bikes)
    - No electrical equipment.
    - No flammables.
    - Mech (Adarash) to submit Change Request regarding Duty/Standby fans requirement.
4. **Waste Management (bin cleaning at stations)**
    - Bin Store not required at Queens Park and Carlisle. Passengers are encouraged to use public/precinct bins.
    - ALUA (Chris Evans) to RFI for PTA cleaning contractor contact. Post meeting note: @Sim, Frederick in lieu of an RFI, are you able to help arrange a meeting with the PTA cleaning contractor?
5. **Cannington Staff Crib provisions**
    - 10pax: 5 seated at table, 3 seated at bench, 2 standing.
6. **Natural Light Assessment**
    - Not applicable at Queens Park and Carlisle as these stations are not staffed (at day one)

Kind regards,

Mimi Cho
Associate

mcho@hassellstudio.com
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-----Original Appointment-----
From: Sim, Frederick <Frederick.Sim@pta.wa.gov.au>
Sent: Wednesday, 14 September 2022 4:12 PM
To: Sim, Frederick; Kalantary, Shahpoor; Moran, Steven; John-Paul Davies; Archie Temelcos; Shortt, Mervyn; Longville, Ian; Mimi Cho; Asokan,Harish; Bilyk, Konstantin; Hannah Galloway; Ian Stanger; Vidovich, Jake; Ben Johnston
Cc: Ben Hoy; Temelcos, Archie; Jens Wurster; Jacques Bezuidenhout
Subject: LXR Detailed Design Sessions 15/12 (Teams Only)
When: Thursday, 15 December 2022 9:00 AM-10:00 AM (UTC+08:00) Perth.
Where: Microsoft Teams Meeting

Update: Agenda;

- Urban Design update (Noise Wall / boundary intent and Queens Park Public Realm)
- Queens Park canopy reduction to accommodate EST mast at north of platform (impact on canopy length and lighting levels)
- Queens Park Store Room at concourse level
- Cannington Staff Crib provisions
- Waste Management (bin cleaning at stations)

Hi all,

Just booking the recurring meeting on Thursday timeslot in all our calendars until the end of the year.

If the meeting is not required, we'll send out the cancelation

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—

Microsoft Teams meeting

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—

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 the 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 3-25 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 are indicated by the angles on the circumference of 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 the 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 when the centre of the sun crosses the plane of the earth's equator, and the day and night are of equal length.

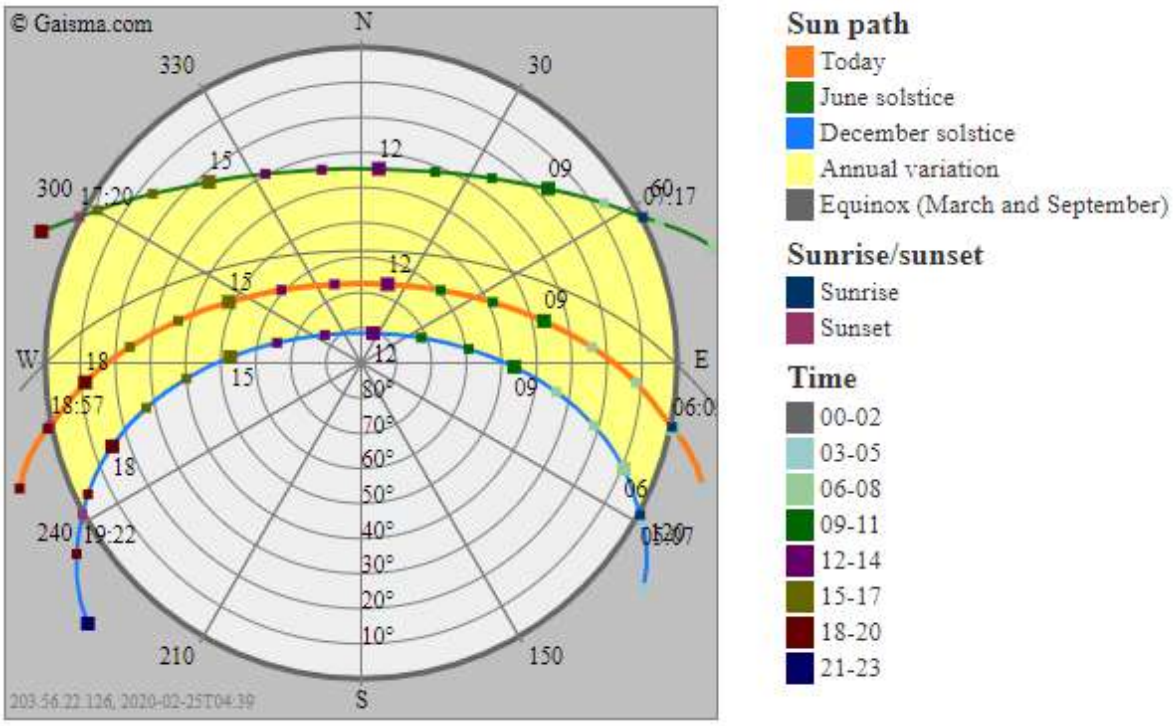

FIGURE 3-25 PERTH SUN PATH DIAGRAM

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 when it is possible for the sun to shine from the Southeast direction at dawn and from the Southwest direction at dusk.

Figure 3-26 below provides an explanation of 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.

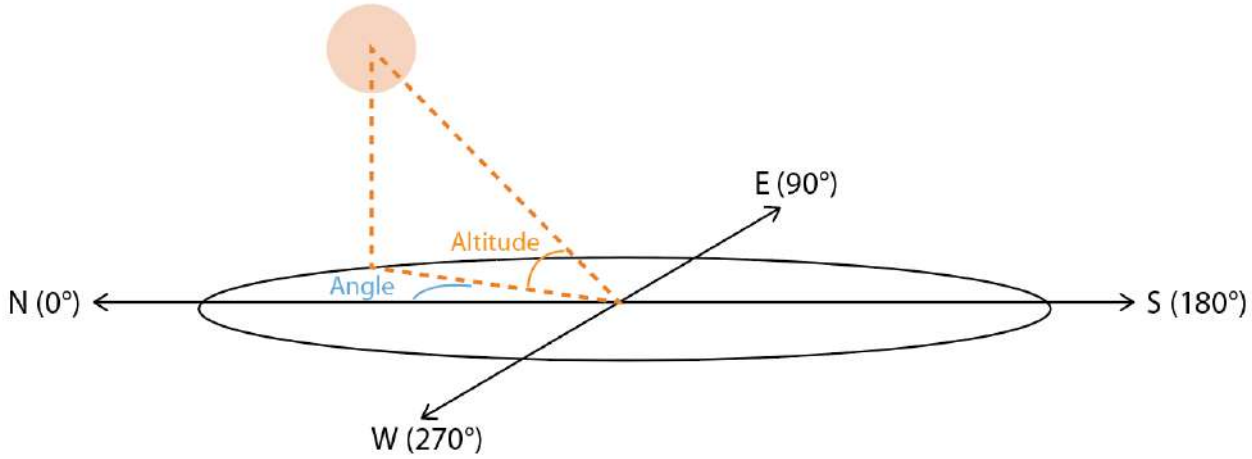

FIGURE 3-26 DEFINITION OF SUN ANGLE AND ALTITUDE

Table 3-13 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 3-13 – SUN ANGLES AND ALTITUDE DURING THE 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

3.4.3 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 3-27 and Figure 3-28 below. Figure 3-27 shows that at 2pm and 6pm the canopy of some portions of the platform receives solar exposure. Figure 3-28 shows that while the canopy protects 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.

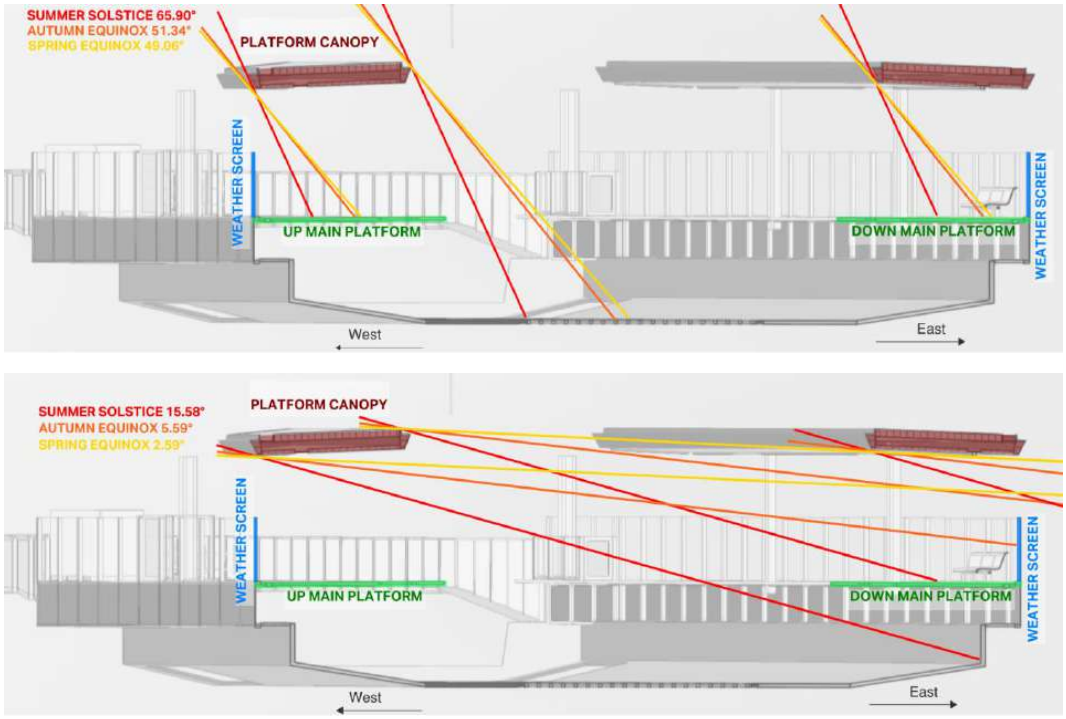

FIGURE 3-27 SUN ALTITUDE AT 2PM (TOP) AND 6PM (BOTTOM)

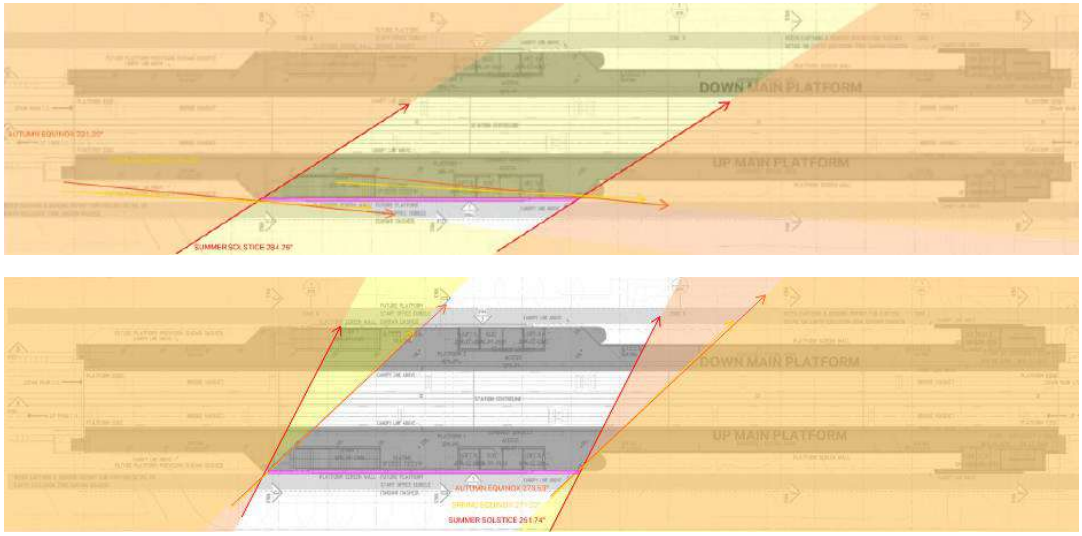

FIGURE 3-28 SUN AZIMUTH ANGLE AT 2PM (TOP) AND 6PM (BOTTOM)

Natural Lighting

An indoor environment that achieves good daylight amenities improves health and well-being 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 amenities.

The Green Star Daylight and Views Hand Calculation Guide assume 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 the desktop/ table level. This is illustrated in Figure 3-29 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

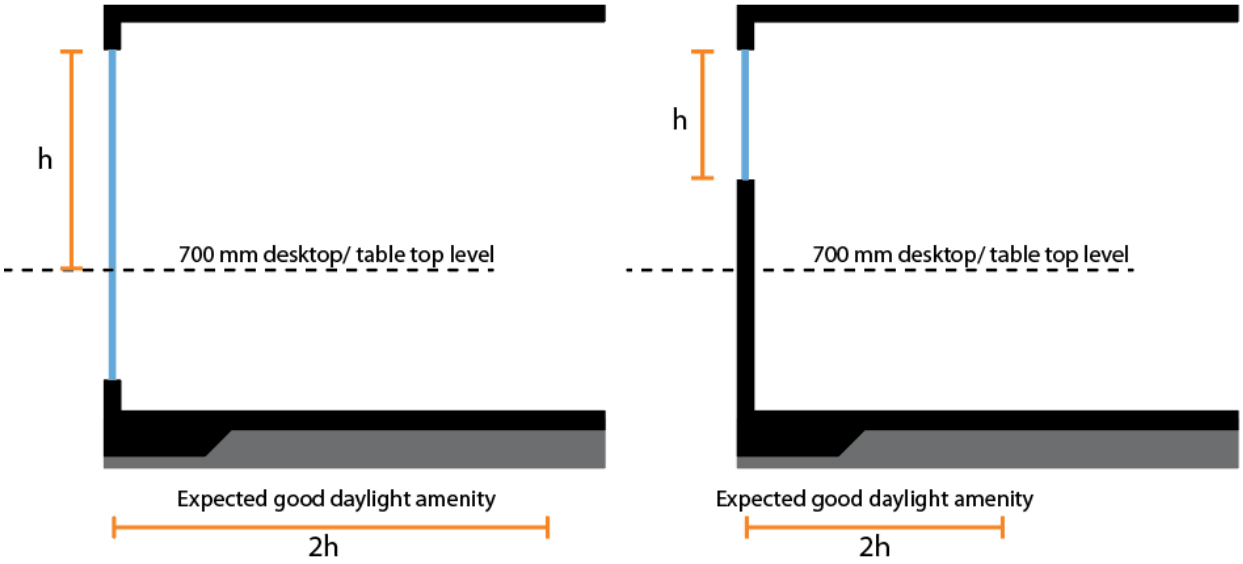

FIGURE 3-29 EXPECTED GOOD DAYLIGHT AMENITY DIAGRAM

The area of expected good daylight amenities can then be compared to the area of the primary space. The area of expected good daylight amenities 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 the risk of solar reflection impacting the train driver's vision.

An example is provided in Figure 3-30 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 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.

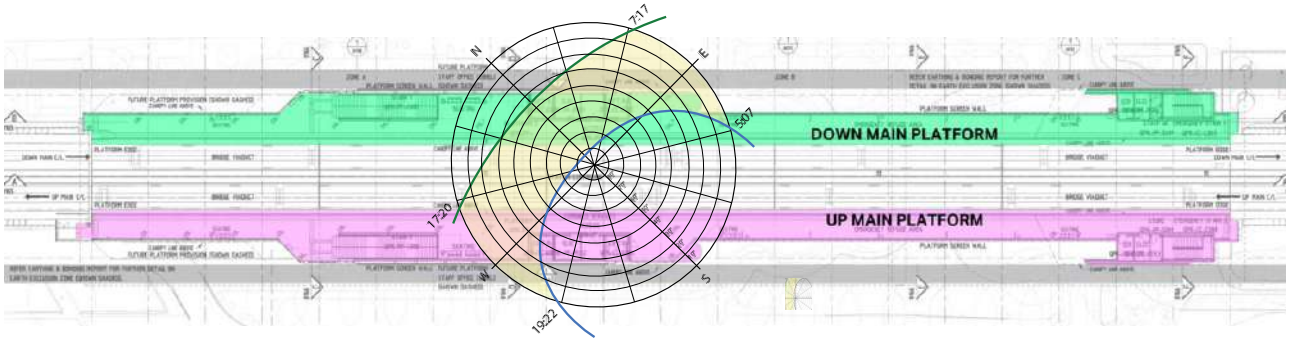

FIGURE 3-30 SUN PATH DIAGRAM

Rain Analysis

The purpose of the rain analysis is to provide advice on the probable rainfall angle and its impact on waiting for 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 refer 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 3-31 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.

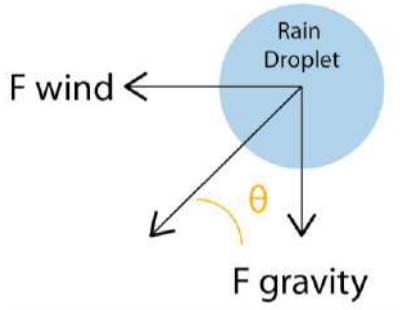

FIGURE 3-31 FORCES ACTING ON THE WATER DROPLET, EXCLUDING DRAG FORCE

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 Newton
- 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.

$$F_{gravity} = \rho_{water} V g$$

EQUATION 2 GRAVITATIONAL FORCE

Where:

- $F_{gravity}$ is the gravitational force in Newton
- 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 a 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 the 95th percentile. These represent the rain rates that 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 3-32.

[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

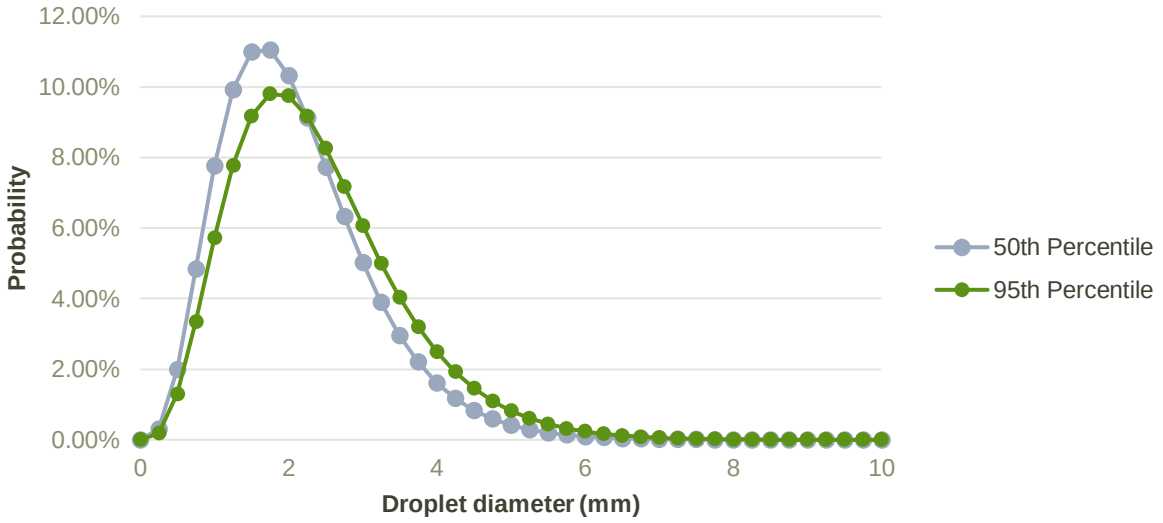

FIGURE 3-32 PROBABILITY DISTRIBUTION OF RAINDROP SIZES BASED ON LAWSON'S (2001) DISTRIBUTION

Based on the rainfall distribution shown in Figure 3-32, the droplet diameter with the highest probability is estimated at 1.75mm in diameter for both the 50th percentile and 95th percentile rainfall rates.

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 3-32 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.

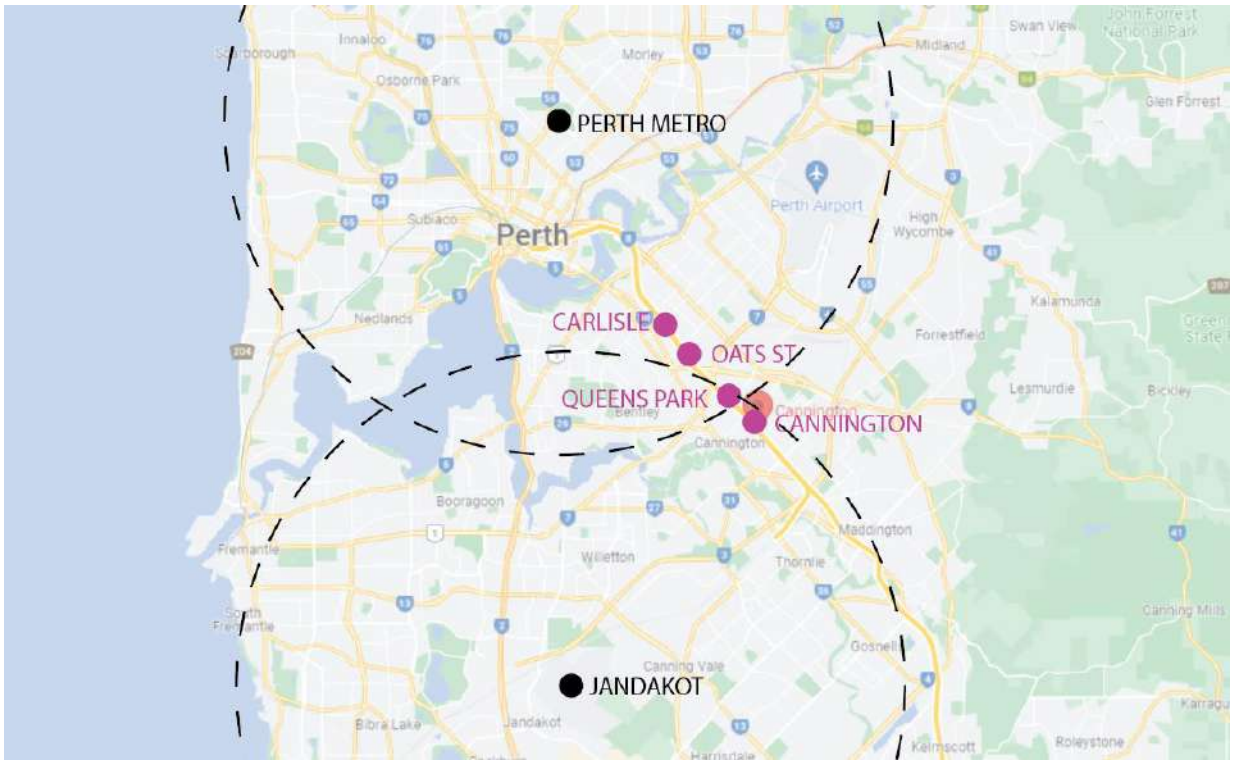

FIGURE 3-33 WEATHER STATION (BLACK) AND STATIONS (PINK)

The data is presented in 10-minute averages for each hour. Wind data from the weather station is assumed to be 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 3-14 and Table 3-15 below show the times of the 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 3-14 – 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 3-15 – FREQUENCY OF RAINFALL BASED ON TIME

Period	Time	Occurrence
Night	0:00 - 06:00	27%

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

Figure 3-34 below shows that when rain is falling, there are two prevailing wind directions:

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

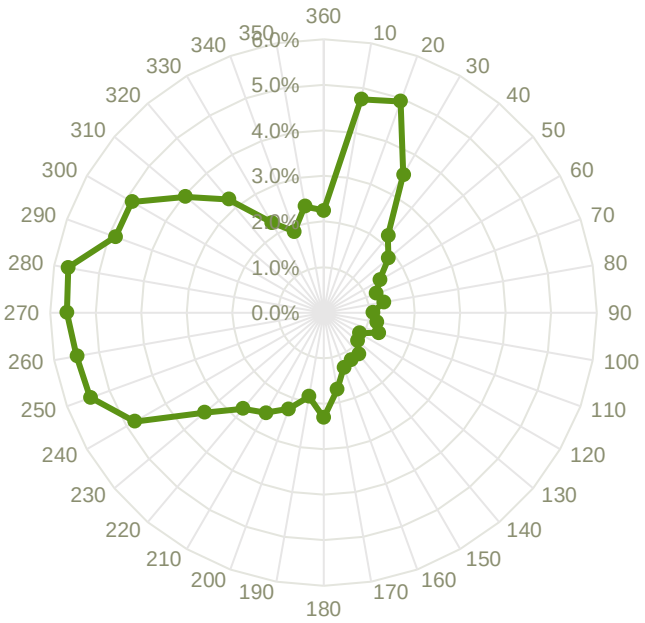

FIGURE 3-34 FREQUENCY DISTRIBUTION OF WINDS DIRECTION WHEN RAINING AT JANDAKOT (2005-PRESENT)

An analysis of 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 3-35 WEST DIRECTION FREQUENCY DISTRIBUTION (1M GROUND LEVEL)

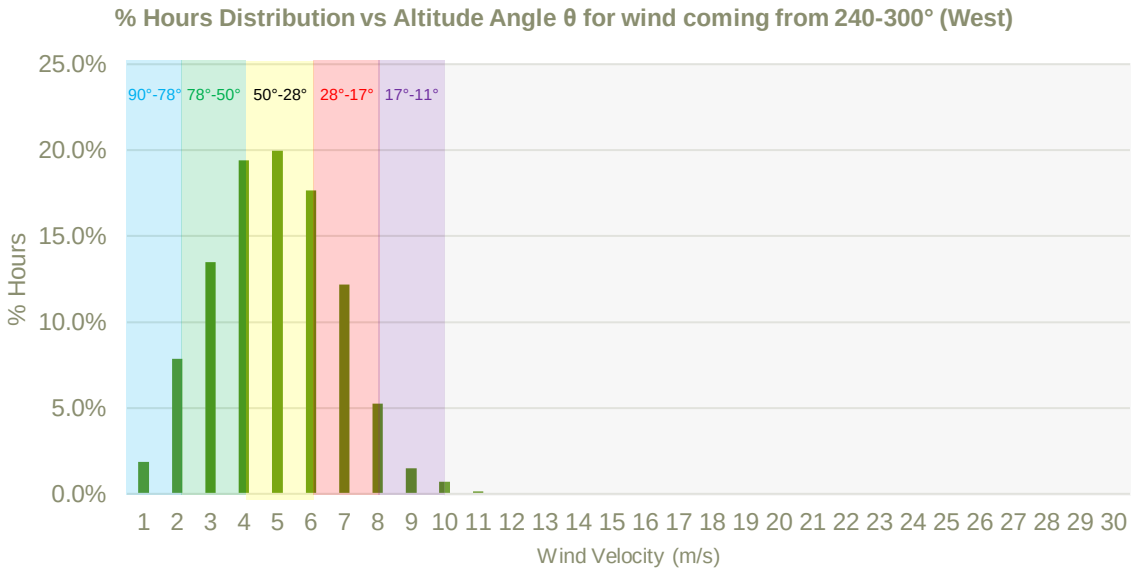

Figure 3-35 shows the following different rain angles and how frequently they occur:

- 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 3-36 NORTH DIRECTION FREQUENCY DISTRIBUTION (1M GROUND LEVEL)

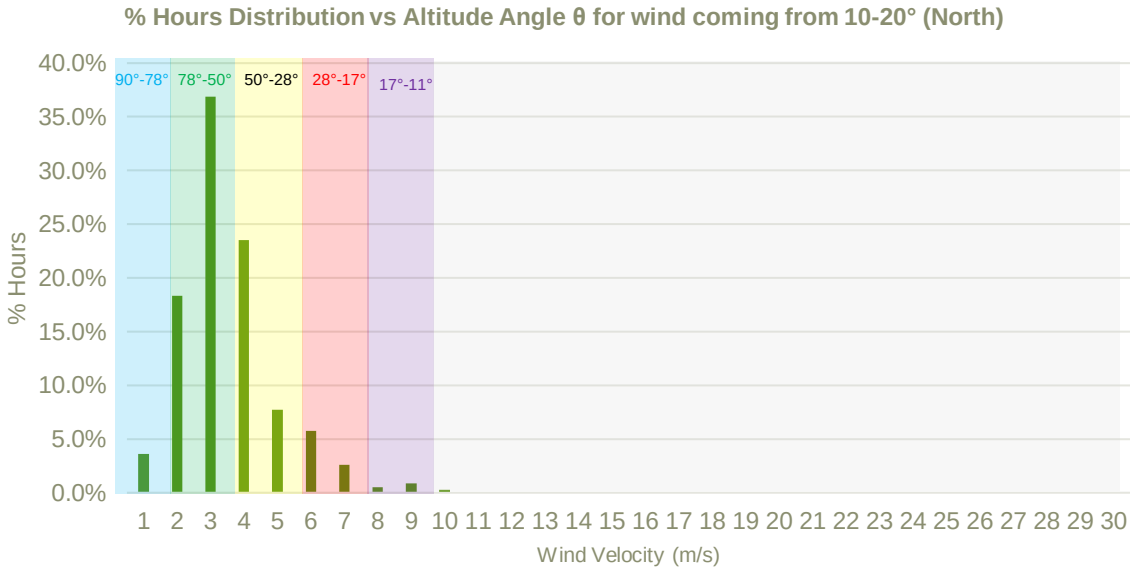

Figure 3-36 shows the following different rain angles and how frequently they occur:

- 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 3-16 and Table 3-17 below show the times of the 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 3-16 – 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 3-17 – 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 3-37 below shows that when rain is falling, there is one prevailing wind direction:

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

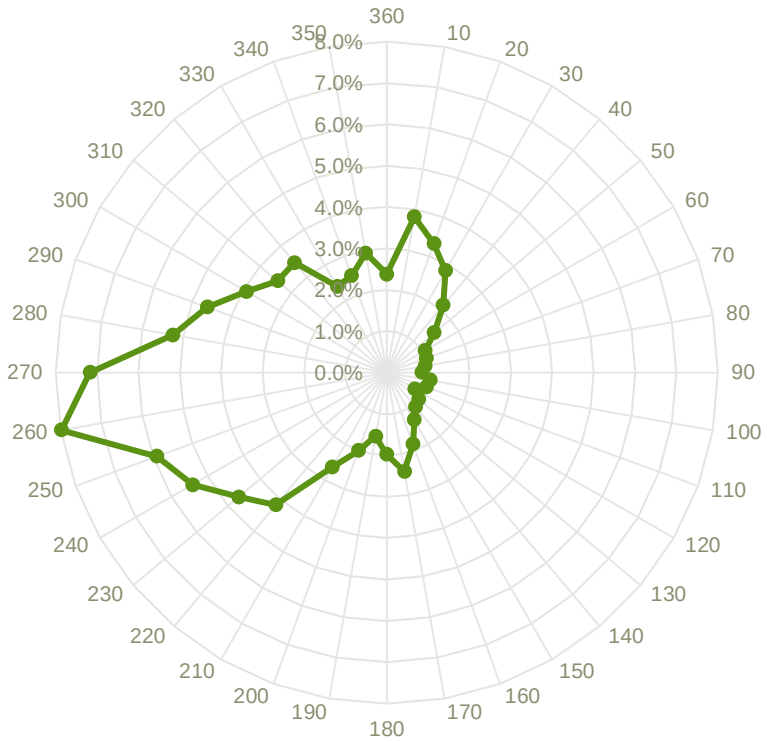

FIGURE 3-37 FREQUENCY DISTRIBUTION OF WINDS DIRECTION WHEN RAINING AT PERTH METRO (2005-PRESENT)

An analysis of 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 3-38 WEST DIRECTION FREQUENCY DISTRIBUTION (1M GROUND LEVEL)

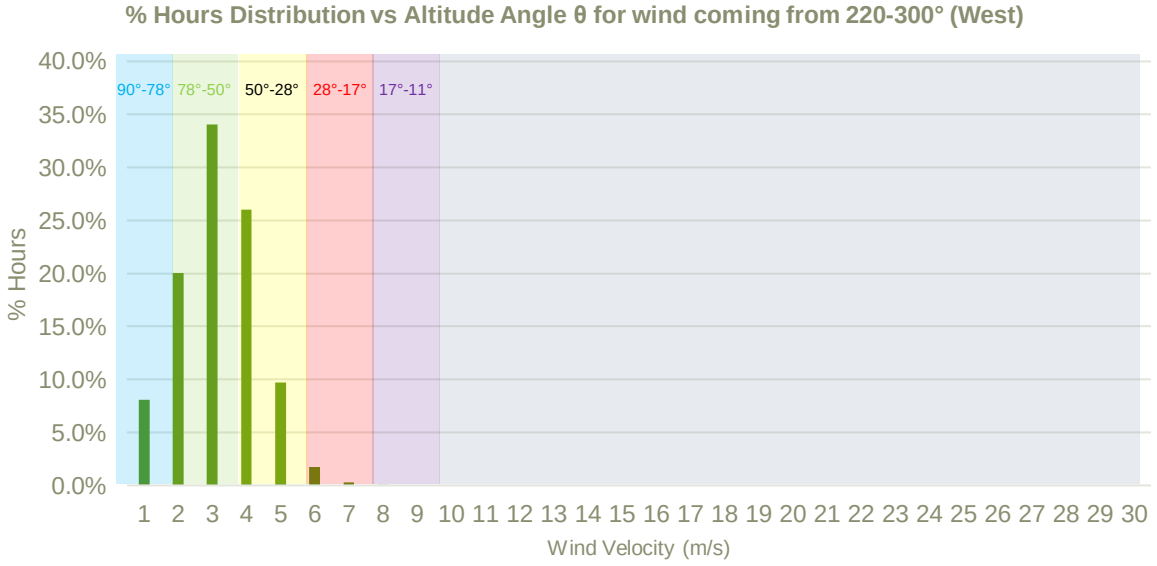

Figure 3-38 shows the following different rain angles and how frequently they occur:

- 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 for passengers on the newly proposed platforms. The methodology for this assessment includes assessing the wind direction and analysing whether the 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 3-18. Wind conditions are unacceptable when the probability of the mean wind speed exceeding the given number is greater than 5%.

TABLE 3-18 – 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 require that windbreaks 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. The frequency distribution of the wind speeds is provided in Figure 3-39 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 criterion, 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

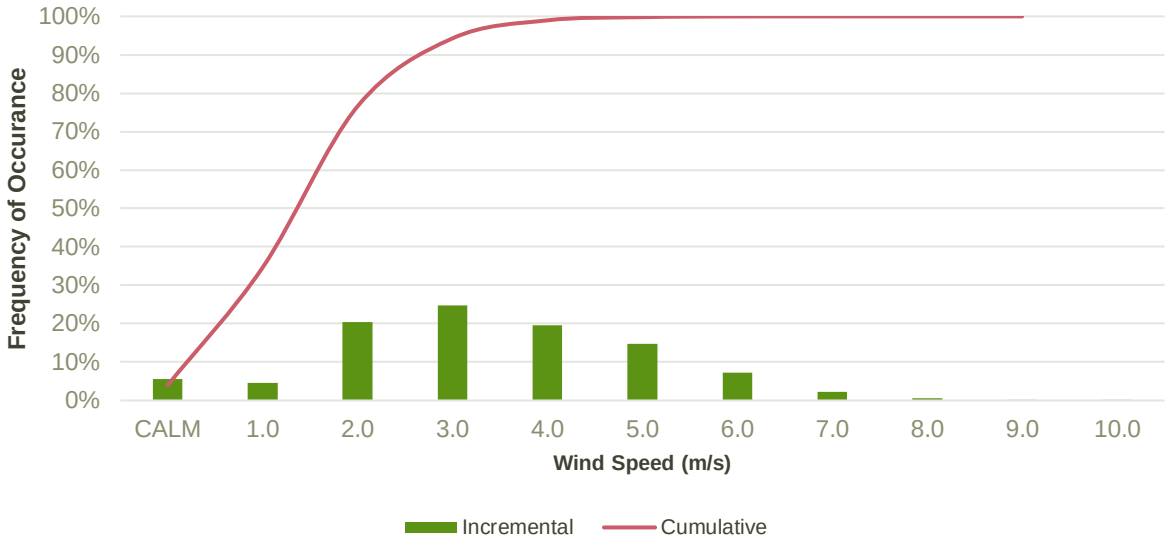

FIGURE 3-39 JANDAKOT WIND SPEED DISTRIBUTION (GROUND LEVEL)

Figure 3-40 demonstrates the wind speed distribution at the platform level. At the platform level, there is a 24% chance of the wind speed exceeding the Lawson comfort criteria.

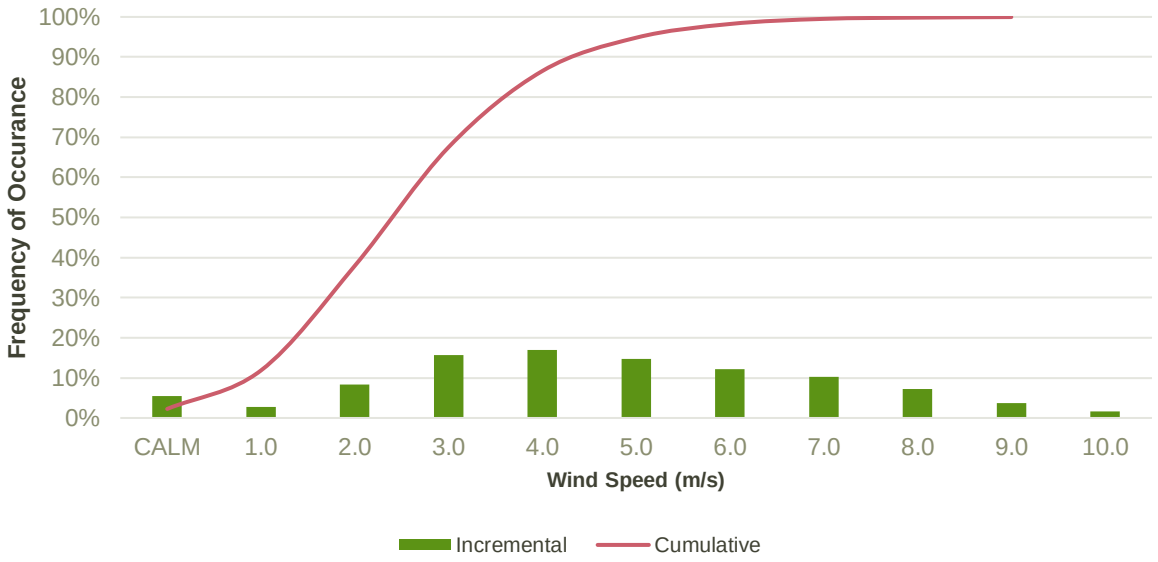

FIGURE 3-40 JANDAKOT WIND SPEED DISTRIBUTION (PLATFORM LEVEL)

To further assess the windspeed and prevailing wind directions, a frequency distribution of the wind direction is provided in Figure 3-41 below.

Figure 3-41 shows that there are three prevailing wind directions:

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

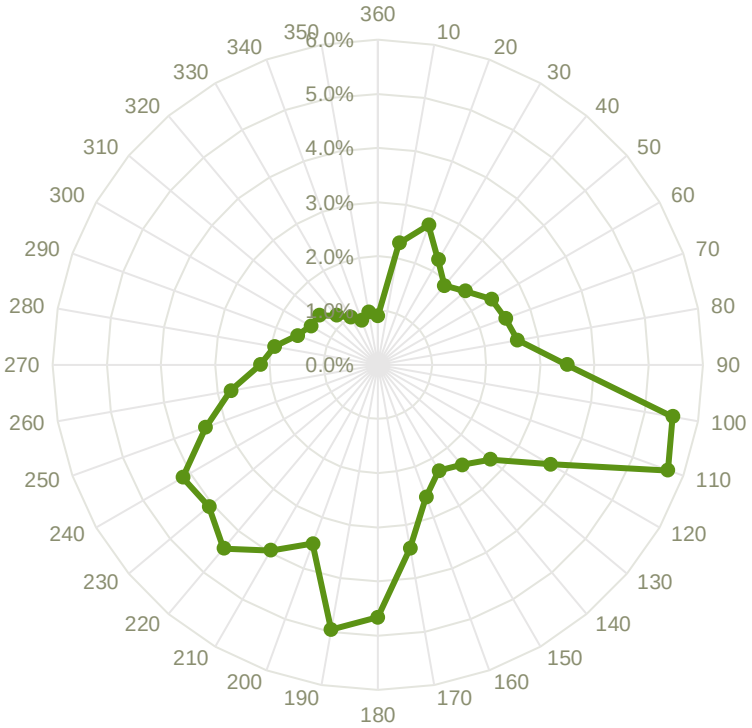

FIGURE 3-41 FREQUENCY DISTRIBUTION OF WINDS DIRECTION AT JANDAKOT (2005-PRESENT)

An analysis of 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 3-42 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 the 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 the time when the wind is occurring a speed of 6m/s is exceeded.

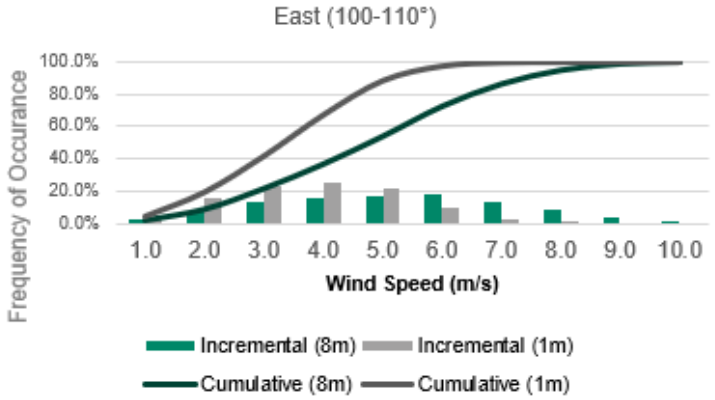

FIGURE 3-42 DISTRIBUTION OF EAST WIND SPEEDS (110 – 110°)

Figure 3-43 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 the wind is occurring at ground level, the speed is greater than 6m/s less than 0.5% of the time. At the platform level when the wind is occurring, speeds exceed 6m/s for approximately 12.4% of the time.

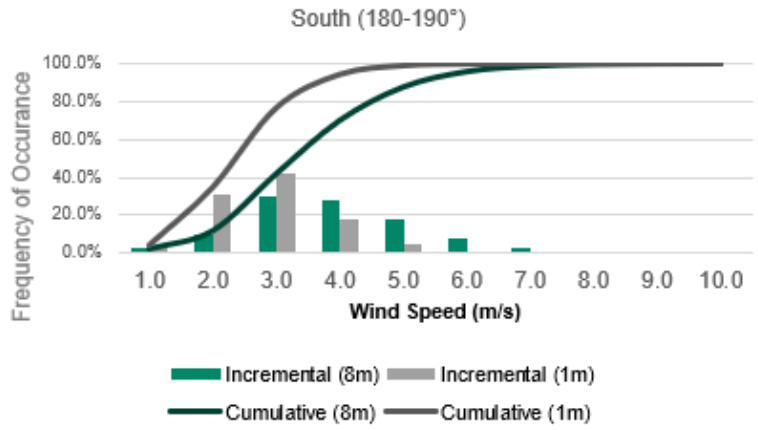

FIGURE 3-43 DISTRIBUTION OF SOUTH WIND SPEEDS (180-190°)

Figure 3-44 below shows the distribution of the wind speeds from the Southwest direction. The figure indicates that at the 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 the 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 the time when the wind is occurring a speed of 6m/s is exceeded.

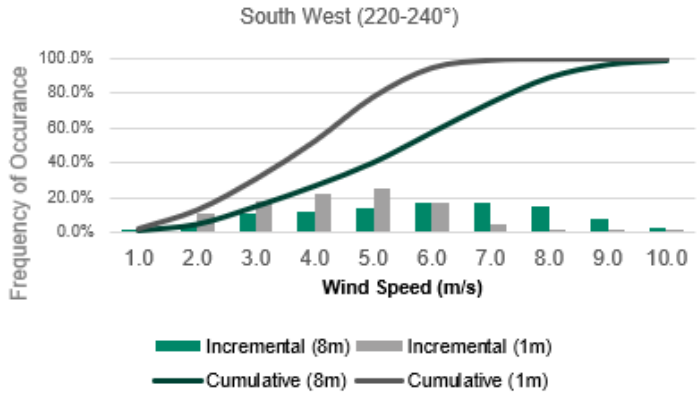

FIGURE 3-44 DISTRIBUTION OF SOUTHWEST WIND SPEEDS (220-240°)

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 the platform level, the comfort criteria are exceeded.

Perth Metro

The average wind speed for Perth Metro at ground level is approximately 2 m/s. Frequency distribution of the wind speeds is provided in Figure 3-45 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 3-45 PERTH METRO WIND SPEED DISTRIBUTION (GROUND LEVEL)

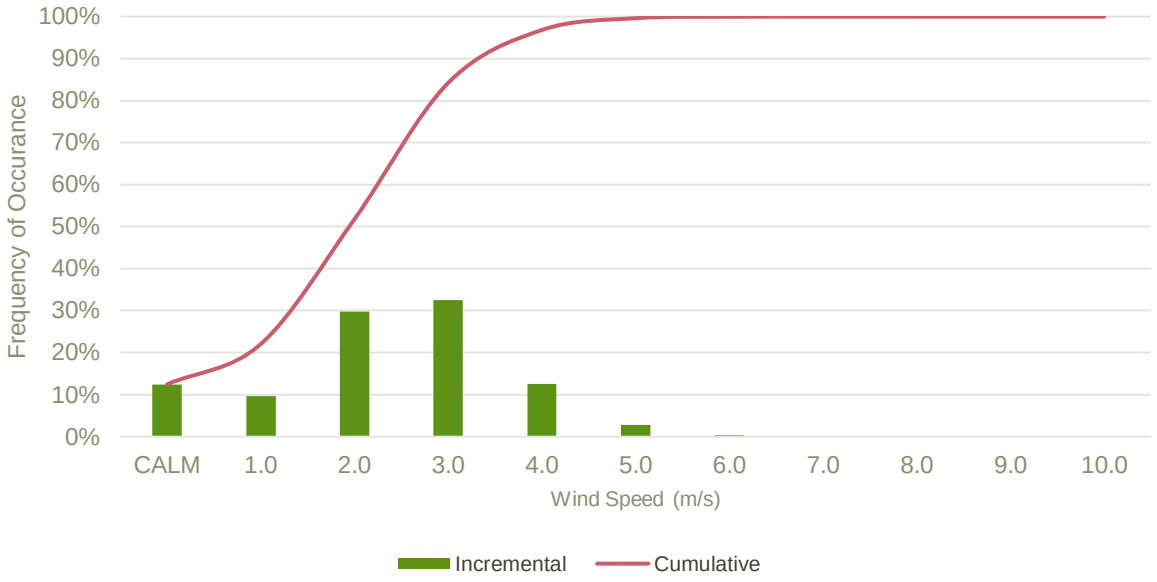

Figure 3-46 demonstrates the wind speed distribution at the platform level. At the platform level, there is a 9% chance of the wind speed exceeding the Lawson comfort criteria.

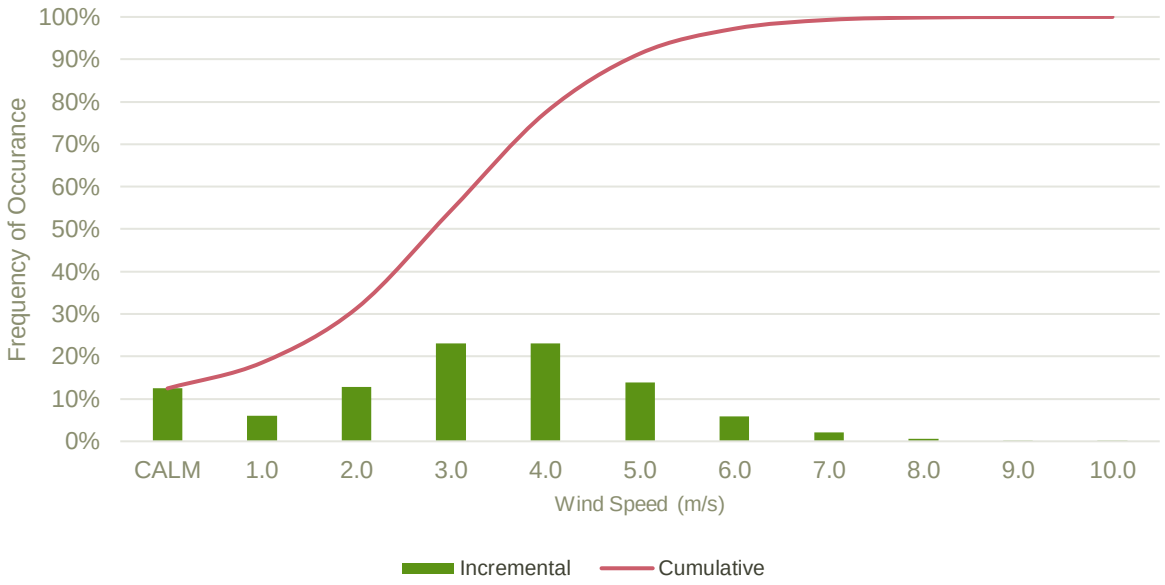

FIGURE 3-46 PERTH METRO WIND SPEED DISTRIBUTION (PLATFORM LEVEL)

To further assess the windspeed and prevailing wind directions, a frequency distribution of the wind direction is provided in Figure 3-47 below.

Figure 3-47 shows that there are three prevailing wind directions:

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

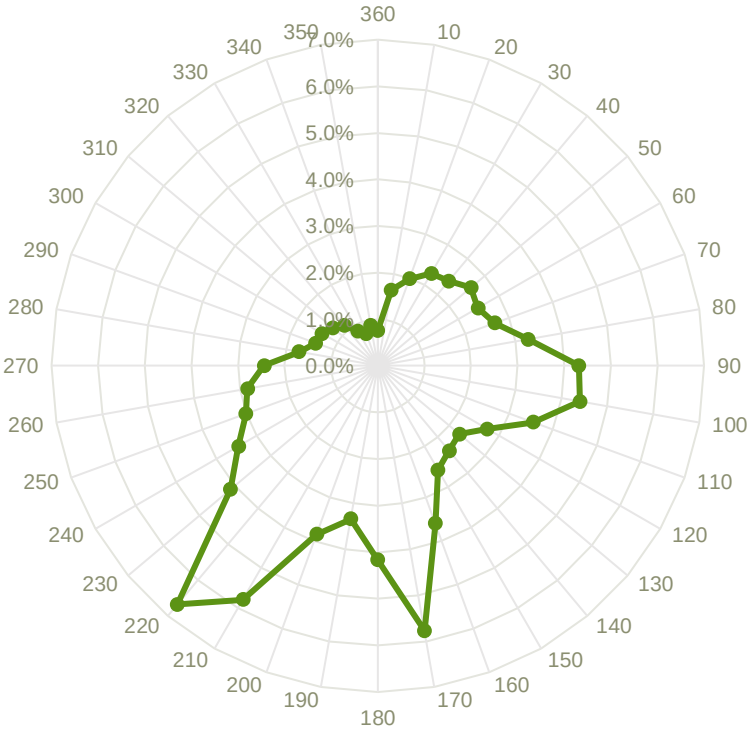

FIGURE 3-47 FREQUENCY DISTRIBUTION OF WINDS DIRECTION AT PERTH METRO (2005-PRESENT)

An analysis of 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 do not include periods where there is no wind (i.e., calm conditions).

Figure 3-48 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 the wind is occurring at ground level, the speed is greater than 6m/s only 2% of the time. At the platform level, the speed is greater than 6m/s 32% of the time.

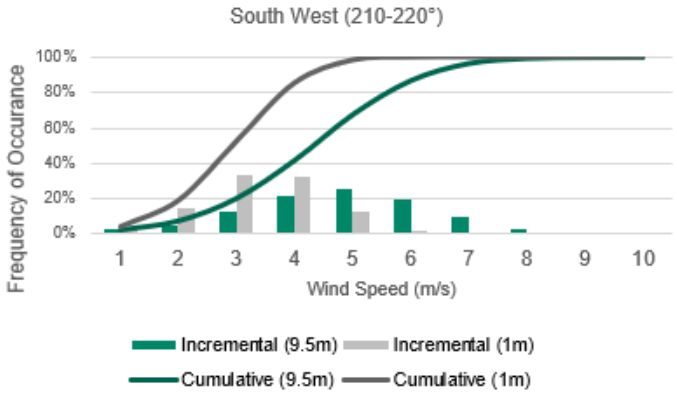

FIGURE 3-48 DISTRIBUTION OF SOUTHWEST WIND SPEEDS (210-220°)

Figure 3-49 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 the platform level, when the wind is occurring a speed of 6m/s is exceeded only 0.2% of the time.

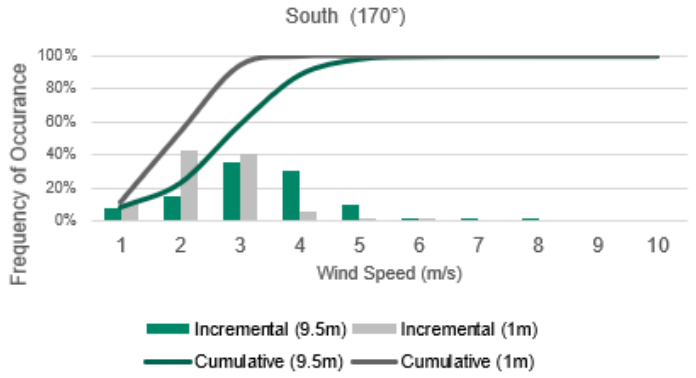

FIGURE 3-49 DISTRIBUTION OF SOUTH WIND SPEEDS (170°)

Figure 3-50 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 the platform level, when the wind is occurring speeds exceed 6m/s 0.2% of the time.

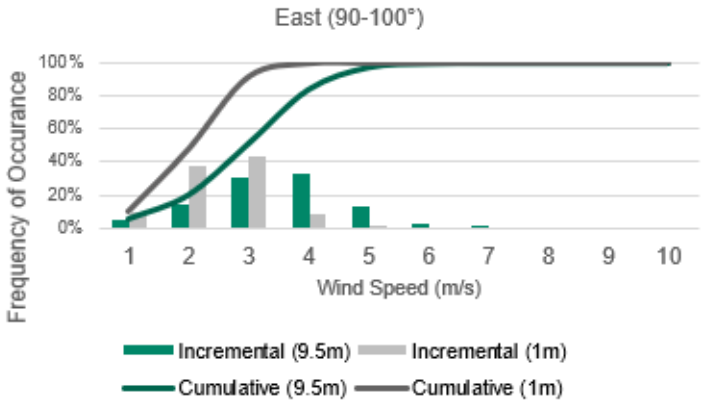

FIGURE 3-50 DISTRIBUTION OF EAST WIND SPEEDS (90-100°)

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.