Macquarie Point Heat Risk and Climate Change Assessment

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Contents

Tables

Figures

1 Introduction

1.1 Purpose of the Report

This report presents the findings of a desktop urban heat island risk assessment to support the development of responses to the Tasmania Planning Commission (TPC) Guidelines: *Macquarie Point Multipurpose Stadium Project of State Significance* (the Guideline). This report specifically responds to the Guideline section: 8.8 Climate change.

The purpose of the report is to develop a better understanding of the current temperature profile of the Macquarie Point Multipurpose Stadium Project Site (Project Site) and of the projected future impacts to the site from changes in the climate. It analyses historical Bureau of Meteorology temperature and remote sensing data to understand the current temperature profile of the Project Site. Publicly available climate projection datasets intersecting with the site was also examined to determine how urban heat influences may impact the Project Site into the future under varying timeframes (e.g. 2030, 2050 and 2090). Further, the report summarises the implications of a changing climate on rainfall and sea level rise relative to the Project Site, noting that overland flooding and coastal inundation risk assessments are reported separately.

Accordingly, this report:

- Sets the baseline knowledge of heat related hazards relevant to the Project Site;
- Summarises information on existing heat related hazards relevant to the Project Site;
- Summarises information on future heat related hazards, as well as projected changes to rainfall and sea level rise relevant to the Project Site;
- Provides recommendations of a range of heat mitigation measures for consideration; and
- Provides an outline of further works/studies supporting proposed development in the Project Site.

1.2 Site Description

The Project Site is located at the foreshore of Macquarie Point in Sullivans Cove, bound to the south by Evans Street, west by Davey Street, Hobart Cenotaph to the north, and Port of Hobart to the east and north-east adjacent to the River Derwent forming part of the TasPorts Macquarie Wharf. The Project Site slopes gently to north-northwest towards Evans Street and the Hobart Cenotaph. It is understood that the proposed development is to be delivered across three broad stages delivering mixed-use precinct with the Mac Point Site being approximately 9.3 hectares.

The Project Site is currently intermixed with carparking, sheds and cleared surfaces with existing structures including the Goods Shed, The Red Square and The Royal Engineers Building. The Project Site will gain vehicular access via Evans Street and two smaller, unnamed roads connected by both the Tasman Highway and Davey Street, which provides access to the existing facilities. TasPorts Macquarie Wharf is accessed via Hunter Street, which is connected to Evans Street, allowing access to the east of the Project Site.

The Hobart Rivulet traverses the northern boundary of the site from west to east before draining into the River Derwent southward of the Doman Boat Ramp.

The Project Site (Mac Point Site), boundaries and locality context are provided Figure 1.1.

Figure 1.1 Project Site and immediate locality context (Source: Macquarie Point Development Corporation, 2023)

1.3 Proposed Development

The proposed development involves the remediation, redevelopment and transition of the Macquarie Point Site into a mixed-use precinct. It is understood that the precinct will include:

- 23,000 seated roofed stadium acting as a multipurpose sporting, arts, events and entertainment facility;
- An Aboriginal culturally informed zone;
- Mixed zoned comprising restaurants, cafes, hotels, medical facilities and commercial office space;
- Antarctic facilities including commercial spaces and connections; and
- Residential area, new public promenade and food and beverage offerings at Regatta Point.

The Project Site will be accessed via active frontages encouraging pedestrian activity, Evans Street and proposed connecting road to the north via the Residential Development and Public Foreshore Zone.

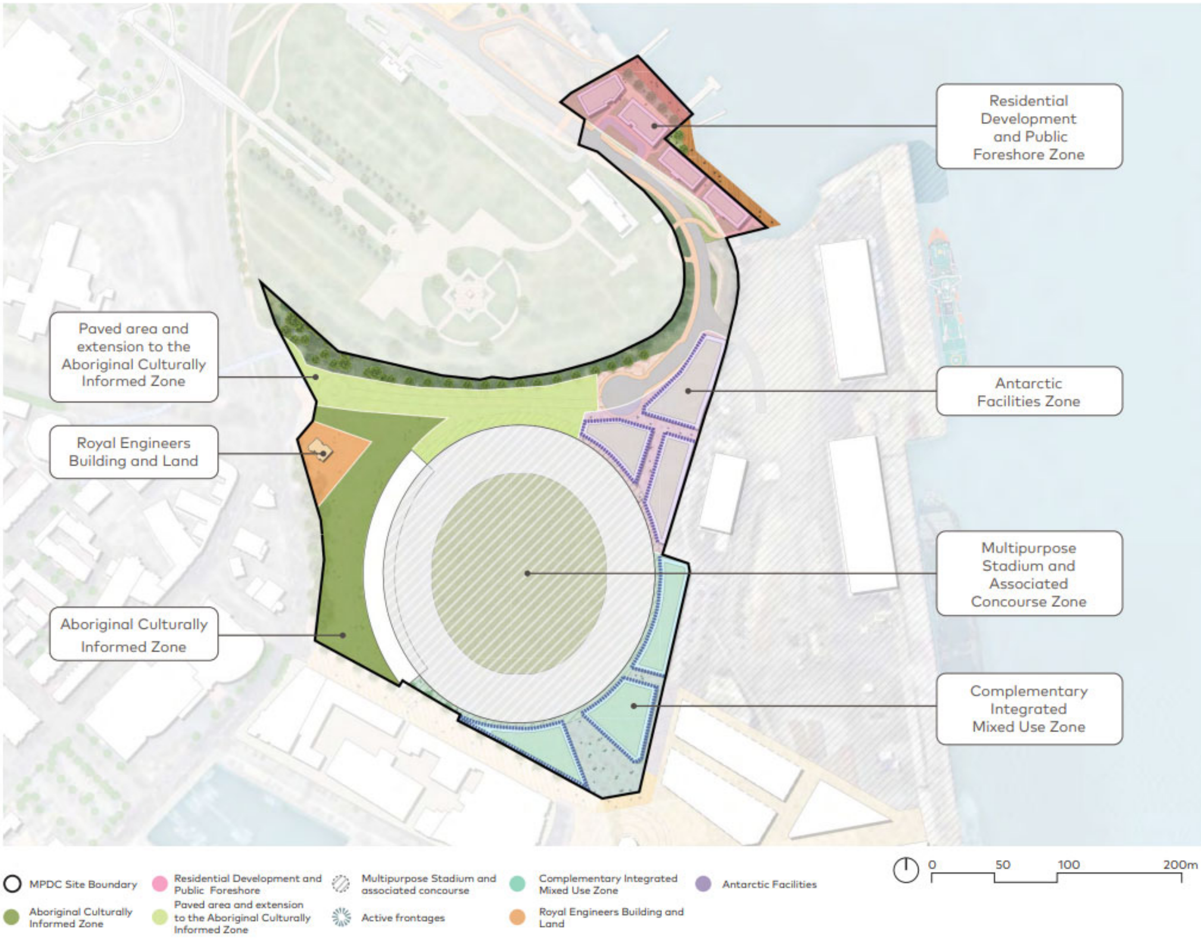


Figure 1.2 Protect Site and immediate locality context (Source: Macquarie Point Development Corporation, 2023)

2 Climate Change Policy & Planning Context

2.1 Local Planning

The *Sullivan's Cove Planning Scheme 1997* sets out the intent for management of use, future development on land and water, and resource consumption activities within the Cove (Hobart City Council, 1998). The planning scheme seeks to advance emerging directions of Tasmania's Resource Management and Planning System and regional strategic planning context via more detailed local responses that take into account the local context. All development within the jurisdiction of the planning scheme is assessed by the City of Hobart.

Town planning in Tasmania is undergoing a transitional period where the *Tasmanian Planning Scheme* (TPS) will replace all local council planning schemes. The incoming *Tasmanian Planning Scheme* sets out local provisions that are applied through zoning maps and detail specific provisions for unique places to address local issues within each local municipality (Tasmanian Planning Commission, n.d.). Currently, there are several planning schemes that remain in effect and will eventually be replaced by a Local Provisions Schedule, this includes the *Sullivan's Cove Planning Scheme 1997* (SCPS). Regardless of the SCPS's eventual replacement, the SCPS is periodically reviewed to ensure that it responds appropriately to the planning changes on a regional and state level.

The SCPS comprises of the following key structural components:

- Strategic framework
- Planning principles for management of activities
- Planning Zones
- Exempt, Permitted, Discretionary and Prohibited Uses of Land
- Objectives and Performance criteria for activities
- Development Plans, Site Development Plans, Management Plans, and Local Area Plans

The SCPS does not currently contain any reference to heatwaves or heat in the context of relating to heatwaves, nor UHI.

Regarding Sea Level Rise, the SCPS indicates that the operation of the Port of Hobart is to default to the relevant safety and hazard distances specified in the relevant Australian standards. Further, section 32.7.9 for Inundation Hazard details the objective for appropriately managing risk from coastal inundation. A1 specifies that:

"*The finished floor level of a habitable room must be not less than 2.8 metres above the Australian Height Datum (AHD).*"

2.2 City of Hobart Climate Change Adaptation Policy

The City of Hobart's Climate Change Adaptation (CCA) Policy was enacted in 2016 and was last updated in 2020. An objective of the CCA Policy is to take all reasonable and practical measures to increase climate change resilience across assets by minimising the exposure of the City to current and future pressures associated with a changing climate (City of Hobart, 2020a). The policy stipulates that the climate impacts and hazards are considered through the City of Hobart's decision making and strategic planning processes. The CCA Policy ensures that Council plans for and manages adaptation to climate change impacts, particularly where such impacts threaten people and property. Further, the CCA Policy stipulates that the latest climate science and information is reflected in City strategic plans, technical climate change guidelines and decision-making processes.

2.3 Sustainable Hobart Action Plan 2020-2025

The *Sustainable Hobart Action Plan 2020-2025* (SHAP) guides the City of Hobart's response to climate change in a practical and community focused manner, addressing sustainability issues that affect the wellbeing of residents, communities and businesses (City of Hobart, 2020).

The SHAP aims to enhance the City's climate action leadership by proposing practical steps, developed in consultation with the community and external stakeholders, to promote sustainability in Hobart. The SHAP ensures this by establishing over 40 individual actions across six areas, which includes "Resilience".

The SHAP identifies the following urban heat related challenges:

- "*Urban heat islands are built areas that are significantly warmer than surrounding areas due to human infrastructure and activities*."
- "*Buildings and paved areas store more heat, resulting in heat-stress-related negative health outcomes for residents. These trends are set to intensify with climate change.*"

One of the Resilience actions in response to this is:

- "*Smart data collection will identify heat islands, helping to prioritise areas for street tree planting. This initiative will include evidence-based communications about the benefits of green infrastructure, trees and nature in urban spaces, as well as a review of which species are planted, to ensure they will be tolerant to the future climate. This initiative will support the City's goal of reaching 40% canopy cover by 2046.*"

Relating to sea level rise, a strategic goal of the SHAP is:

- "*To prepare our city to withstand storm, sea level rise, flood, bushfire and other natural hazards.*"

2.4 City of Hobart: Capital City Strategic Plan 2023

The City of Hobart's *Capital City Strategic Plan 2023* (CCSP) assists in guiding the development of long-term strategies and plans to set priorities and guide practical decision-making. Forming the CCSP, are eight community pillars accompanied by outcomes, being the goals to be achieved, and strategies to achieving these outcomes (City of Hobart, 2023).

Responding to climate change is referenced throughout the CCSP. In particular, outcome 6.4 of natural environment pillar focuses on Hobart being a climate-resilient city with strategies including:

"*6.4.5 Incorporate disclosure of climate change risk and opportunities into the City's planning and operations, finances and risk management.*

6.4.6 Actively map, manage and monitor climate-related risks such as flood and bushfire in collaboration with the community and emergency services.

6.4.7 Invest in resilient infrastructure to deal with extreme weather events."

2.5 Southern Tasmania Regional Land Use Strategy 2010-2035

The Southern Tasmania Regional Land Use Strategy 2010-2035 (STRLUS) is the Tasmanian Government's strategy to facilitate and manage change, growth and development of Southern Tasmania over the following 25 years. The strategy was prepared in collaboration with the region's 12 local governments, including Hobart, which manages the Project Site. Increased temperatures resulting from climate change are recognised within the 'A Changing Climate' chapter of the strategy (Southern Tasmanian Councils Authority, 2011).

While the strategy doesn't specifically detail any measures or policy responses to address urban heat or heatwave, the strategy does state that:

"*Land use planning can help the community prepare and adapt for the hazards and risks that climate change pose to our natural and built environments..*"

The strategy does specifically detail regional policies responding to climate change and sea level rise. Regional Policy C2 states:

"*Ensure use and development in coastal areas is responsive to effects of climate change including sea level rise, coastal inundation and shoreline recession.*"

Regional Policy C2 is to be achieved by:

"*C2.1 Include provisions in planning schemes relating to minimising risk from sea level rise, storm surge inundation and shoreline recession and identify those areas at high risk through the use of overlays.*"

2.6 State Coastal Policy 1996

The *State Coastal Policy 1996* (SCP) outlines the strategic policy direction of the Tasmanian Government regarding the sustainable development of natural and physical resources, as well as the management and protection of the environment in Tasmania's coastal area. The strategic policy direction outlined in the SCP is to be integrated land use planning controls, and in local council strategic and operational plans (Department of Premier and Cabinet, 1996).

The SCP aims to safeguard the natural and cultural significance of the coast, enable sustainable utilisation and development of coastal resources, and encourage collaborative efforts for its comprehensive management and protection.

There are two specific outcomes in the SCP accompanying the principle of "Natural and cultural values of the coast shall be protected" relating to coastal hazards and climate change. These outcomes stipulate that the SCP will:

"*1.4.1 Areas subject to significant risk from natural coastal processes and hazards such as flooding, storms, erosion, landslip, littoral drift, dune mobility and sea-level rise will be identified and managed to minimise the need for engineering or remediation works to protect land, property and human life*

1.4.3 Policies will be developed to respond to the potential effects of climate change (including sea-level rise) on use and development in the coastal zone."

2.7 State Planning Provisions

The State Planning Provisions (SPPs) incorporate a Coastal Inundation Hazard Code. The coastal hazard codes support the outcomes of the *State Coastal Policy 1996* previously listed and are predominately applicable to sea level rise (Planning in Tasmania, 2021).

These codes consist of regulations and mapping ('overlays') that manage the use and development within 'hazard bands'. Hazard bands are a mapping element that shows the risk posed by each hazard in specific areas and dictate the necessary planning and building controls. It's important to note that hazard bands do not guarantee that land will be inundated or eroded, but rather indicate that the land is vulnerable to such occurrences.

Hazard bands used to classify risk in the code include:

- Acceptable: The area will be unaffected by coastal inundation by coastal inundation until after 2100.
- Low: land projected to be vulnerable to a 1% Annual Exceedance Probability (AEP) storm surge event by the year 2100.
- Medium: Land projected to be vulnerable to a 1% AEP event by the year 2050.
- High: Land potentially vulnerable to the current mean high tide and sea level rise by the year 2050.

Sea level rise allowances for Hobart are 0.23m by 2050 and 0.85m as per the Tasmanian Local Council Sea Level Rise Planning Allowances released by the Department of Premier and Cabinet (Department of Premier and Cabinet, 2016). The CSIRO was engaged by the Tasmanian Government to provide updated sea level rise planning allowances for Tasmania (CSIRO, 2016). These Sea Level Rise Planning Allowances are based upon the projections from the Intergovernmental Panel on Climate Change's (IPCC) Assessment Report 5 (IPCC, 2013).

The high emissions scenario (RCP8.5) have been adopted for the basis for these projections informing the sea level rise allowances.

2.8 Climate Change (State Action) Act 2008

The *Climate Change (State Action) Act 2008* (CCA) aims to assist the State in addressing the challenges posed by climate change and contribute to the broader national and international response to those challenges and for related purposes (The Department of Premier and Cabinet, 2022). While the CCA does not specifically allude to UHI or heatwaves, the use of climate change can be broadly interpreted as encompassing UHI, heatwave, changes in rainfall pattern and sea level rise, as well as other associated climate change impacts. The objectives of the Act specifically state:

"*(c) identify, promote and support measures to help Tasmania adapt to climate change and to manage the risks and opportunities of a change climate;*"

The CCA then legislates the preparation of a climate change action plan within the commencement of the Act that are to be renewed every five years thereafter. As stipulated by CCA, the actions in the climate change action plan must:

"*(b) build resilience to the impacts of a changing climate through adaptation measures; and*

(c) manage climate-related risks and take advantage of potential opportunities from a changing climate."

2.9 Tasmania's Climate Change Action Plan 2023-25

Legislated by the *Climate Change (State Action) Act 2008*, Tasmania's Climate Change Action Plan 2023-25 details actions that are to be enacted and the approach to implementing these actions (Climate Change Office, 2023). Actions specifically related to heat and climate change include:

- "*Support actions that protect vulnerable Tasmanians from the impacts of climate change, such as bushfires, extreme heat and cold weather events.*"
- "*Ensure the impacts of climate change are considered in Tasmania's planning policies and regional land use strategies and planning regulations.*"
- "*Work across state agencies to establish sustainability and resilience best practice principles in the planning and delivery of infrastructure*."

2.10 Tasmanian Disaster Risk Assessment 2022

The Tasmanian State Disaster Risk Assessment 2022 (TASDRA) delivers an overview of current and future natural hazard risks resultant of a changing climate in Tasmania, for use by all levels of government. The TASDRA provides case studies and information on heatwaves and the related impacts on human health and wellbeing. The TASDRA recognises the risk of heatwaves and the relation to bushfire, particularly to vulnerable groups and that Tasmanian infrastructure, houses, schools and buildings are not generally built for high heat (SES & University of Tasmania, 2022). The TASDRA recognises that design and siting can play an important role in minimising the impact of heatwaves.

The assessment identifies the following heatwave related challenge:

"*Heatwave and smoke exposure are two hazards where homes and other buildings can provide shelter and protect people's health and wellbeing. However, Tasmanian infrastructure, houses, schools and other public buildings are generally not built for high heat. Many Tasmanians live in housing lacking insulation.*"

The TASDRA provides case studies and information related to sea level rise and changes in rainfall patterns, focusing on projected changes and consequences. It recognises that climate change is interlinked with global sea level rise and is projected to amplify coastal inundation, especially during coastal storm surge. The TASDRA acknowledges the existence of legacy developments and assets in exposed coastal areas that are at risk from climate change induced sea level rise and details adaptation options to mitigate this risk. As per the TASDRA, adaptation to sea level rise may include:

- "*Defending current settlements – for example, building levees'*
- *Accommodating, for example, changing buildings to cope with periodic flooding; and*
- *Retreating.*"

As part of its key areas to reduce risk/increase resilience, the TASDRA highlights the importance of strategic land use planning policies, building regulations and their implementation. These factors are important in determining the placement and quality of buildings and other assets.

3 Project Site: Current & Future Climate

3.1 Current Climate

3.1.1 Temperature

The City of Hobart has a temperate, maritime climate with relatively mild and humid winters in contrast to dry and warm summers. This results in a relatively small annual temperature range unlike inland locations. Like many other Australian coastal settlements, Hobart has a higher population density in coastal areas compared to inland areas of Tasmania. Coastal areas also tend to have relatively cooler and less humid conditions compared to inland areas. The climatic statistics from the Hobart (Ellerslie Road, approximately 1.2 km from the Project Site) and Campania (inland approximately 26km north-east from Ellerslie Road) weather stations support this (Figure 3.1).

Between January and March, the average monthly maximum (daytime high) temperature in Hobart (Ellerslie Road) is between 30°C and 34°C, whereas Campania it is slightly higher (between 32°C and 35°C). The opposite pattern occurs at night (summer monthly minimum temperature) with Hobart (Ellerslie Road) ranging between 6°C and 7°C compared to 3°C and 5°C in Campania. The hottest month in Hobart (Ellerslie Road) is January and coolest is July. The winters are cool with monthly average overnight temperatures around 0.4°C in July around Hobart (Ellerslie Road).

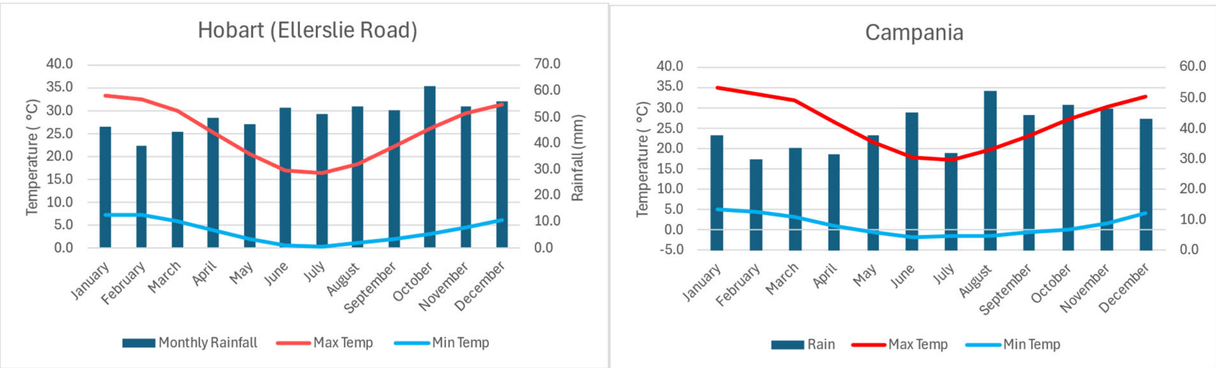


Figure 3.1 Climate statistics from Hobart (Ellerslie Road) (left) and Campania (right). Data are averaged across all available data years. Data source: Bureau of Meteorology.

Solar Exposure

Solar radiation is the primary heat source in urban areas, making it crucial to understanding its balance in the urban climate system. The amount of energy from the sun received by an urban surface at any given time depends on the mean distance of the area from the sun, known as the 'solar constant'.

Solar radiation is the total amount of solar energy falling on a horizontal surface and that energy reaching the ground is dependent on several factors. The two main factors being the position of the sun in the sky and the extent of cloud cover. Cloud cover directly influences the amount of solar exposure at the surface. Southern coastal areas, such as Hobart, typically have higher moisture content, greater and more frequent cloud cover and therefore a lower solar exposure. While cloud cover is unpredictable, the sun's position is not.

The influence of the sun's position on solar exposure can be seen in monthly climatologies, in particular the difference between June and the summer months of December and January. As Hobart is a southerly city, the level of solar exposure in June is lower given the sun appears lower in the sky. In contrast, the solar exposure is higher in summer months, such as December and January, as the sun appears higher in the sky. Figure 3.2 demonstrates this variation in solar exposure.

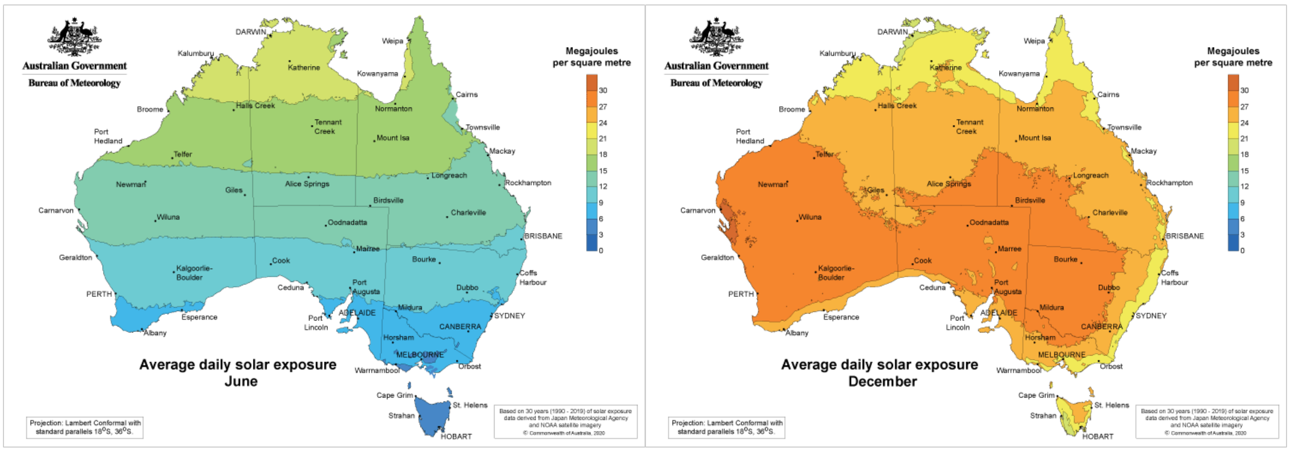


Figure 3.2 Average daily solar exposure difference between June and December (Source: BoM)

Solar exposure analysed from the period of 1990 to 2019 found that annual solar exposure for the site is 13.62MJ/m^2, 23.35MJ/m^2 for December, 23.19MJ/m^2 for January and 4.6MJ/m^2 for June. The maximum solar exposure measured for Hobart (Ellerslie Road) for December was 24.1MJ/m^2 (2021) and 26.7MJ/m^2 for January (2009). This indicates that solar exposure is at its peak during December and January, and significantly drops in winter. For comparison, this is slightly lower than Brisbane's 23.9MJ/m^2 December and 23.31MJ/m^2 January readings.

The level of solar exposure is an influential factor for surface albedo (surface reflectivity) and emissivity (the measure of how quickly a surface emits absorbed heats), which are both contributing factors to heatwave severity and risk.

It is noted that initial BoM observations derive from approximately 22km^2 grids and the Hobart (Ellerslie Road) BoM weather gauge is approximately 1.2km from the Project Site. The solar radiation figures may not be an accurate representation of the site.

Humidity

Humidity from the Hobart (Ellerslie Road) weather station varies across seasons. Humidity it at its highest between March to August, peaking in June with a monthly average at 9am of 78% and 64% at 3pm (Figure 3.3). Lowest monthly averages occur in November and January, with December recording 58% at 9am and 49% at 3pm. Higher humidity along with higher temperature causes outdoor thermal discomfort resulting in impacting outdoor activities such as movement of tourists and pedestrians in Hobart City.

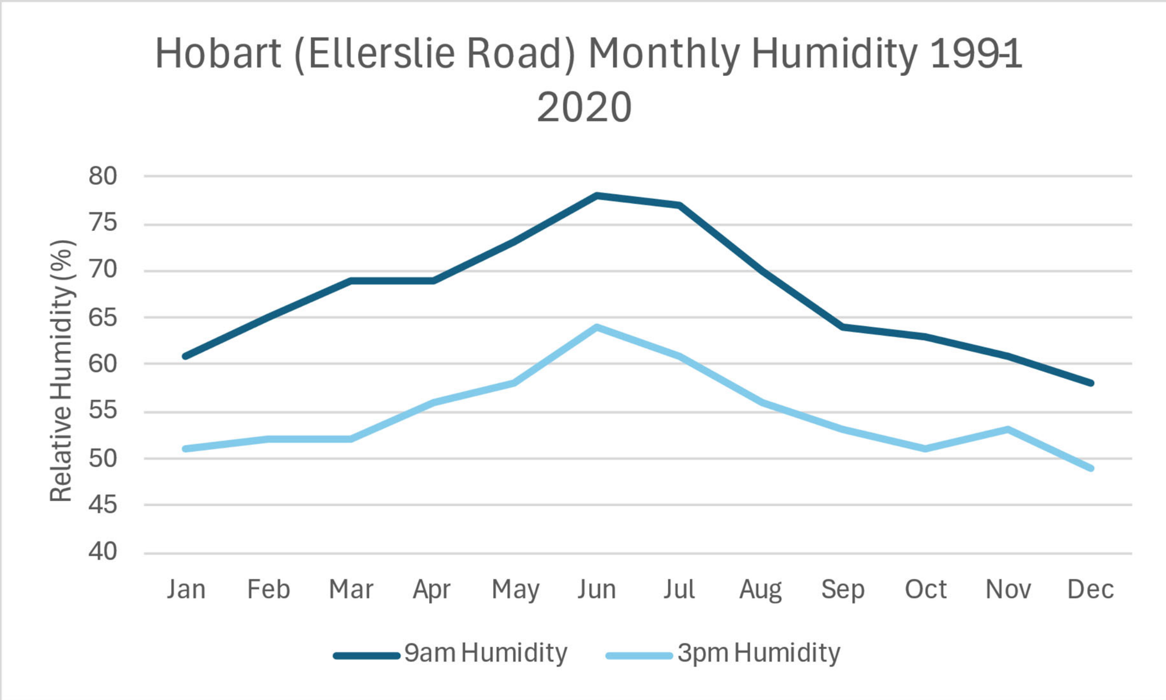


Figure 3.3 Monthly relative humidity in Hobart (Ellerslie Road) (094029) based on data from 1991 to 2020. Date source: Bureau of Meteorology

Heatwaves in Hobart

The average annual number of hot days (days >30°C) and very hot days (days 35°C) for Hobart (Ellerslie Road) is 6.3 and 1.2 respectively. Between 2003 and 2023, Hobart (Ellerslie Road) recorded 179 days where the maximum temperature reached or exceeded 30°C and 35 days where the maximum temperature reached or exceeded 35°C as shown in Figure 3.4

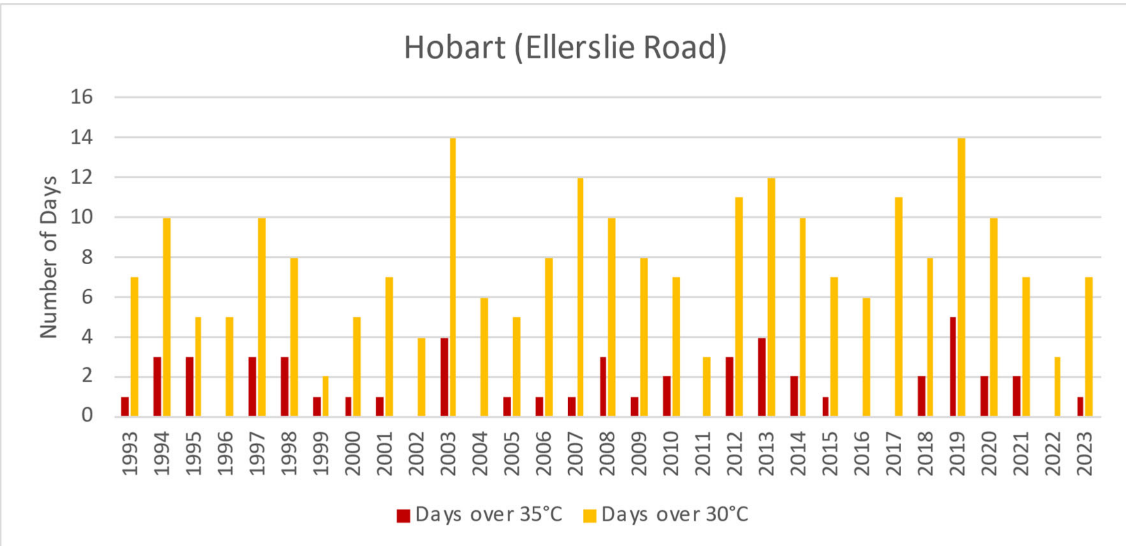


Figure 3.4 Annual count of hot days (>30°C) and very hot days (>35°C) for Hobart (Ellerslie Road)

When analysing the historical temperature data for Hobart (Ellerslie Road), January was found to have the highest concentration of days reaching or exceeding 35°C with 24 days recorded as shown in Figure 3.5. This was closely followed by February (13 days), then December (9 days) and March (4 days).

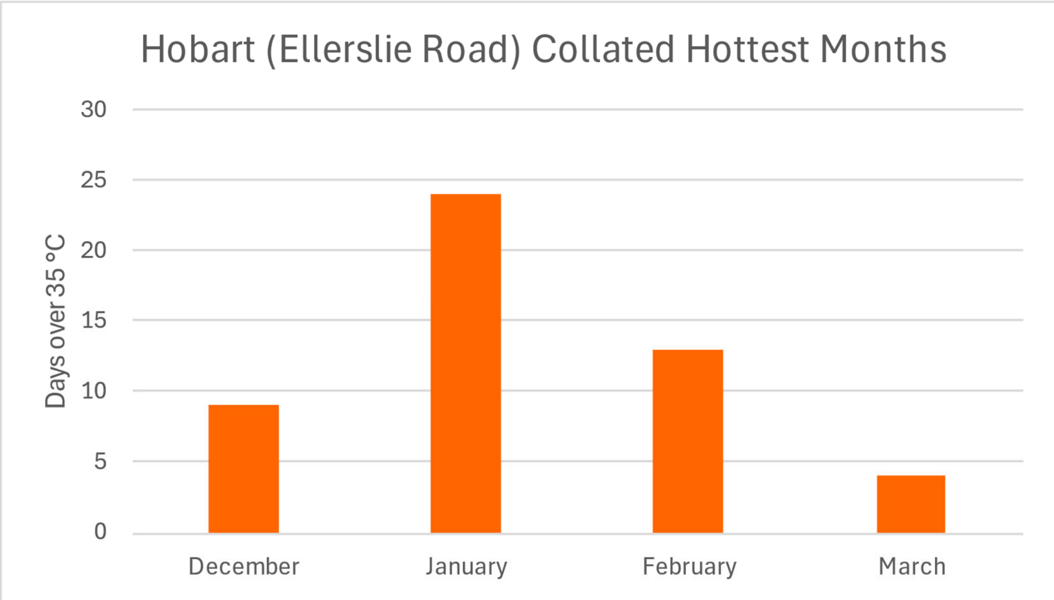


Figure 3.5 Monthly count of very hot days (>35°C) for Hobart (Ellerslie Road)

Extreme heat associated with heatwaves and the urban heat island effect is already impacting communities across Australia, with Tasmania becoming increasingly more susceptible to heat that will likely have a larger impact in future climates.

The BoM defines heatwaves as three or more consecutive days of hot weather that is unusual for the location. Heatwaves are a major concern due to their potential impacts on human health, infrastructure and operational activities. In Figure 3.6 the following definitions apply:

- Heatwaves (a period of hot days): This is a count of occurrence where both the maximum and minimum temperatures are above normal (the 85th percentile of historical data) for that location for **three or more consecutive days** (Source: BoM). This includes all three types of heatwaves (low, severe and extreme intensity).

- Longest heatwave: the number of consecutive days where both the maximum and minimum temperatures are above normal (the 85th percentile of historical data) for that location in a particular year.

The highest annual count of heatwaves recorded at Hobart (Ellerslie Road) occurred in 2015 (5 occurrences), with the longest duration of heatwaves in 2013 and 2017 where heatwave conditions lasted for seven consecutive days (Figure 3.6).

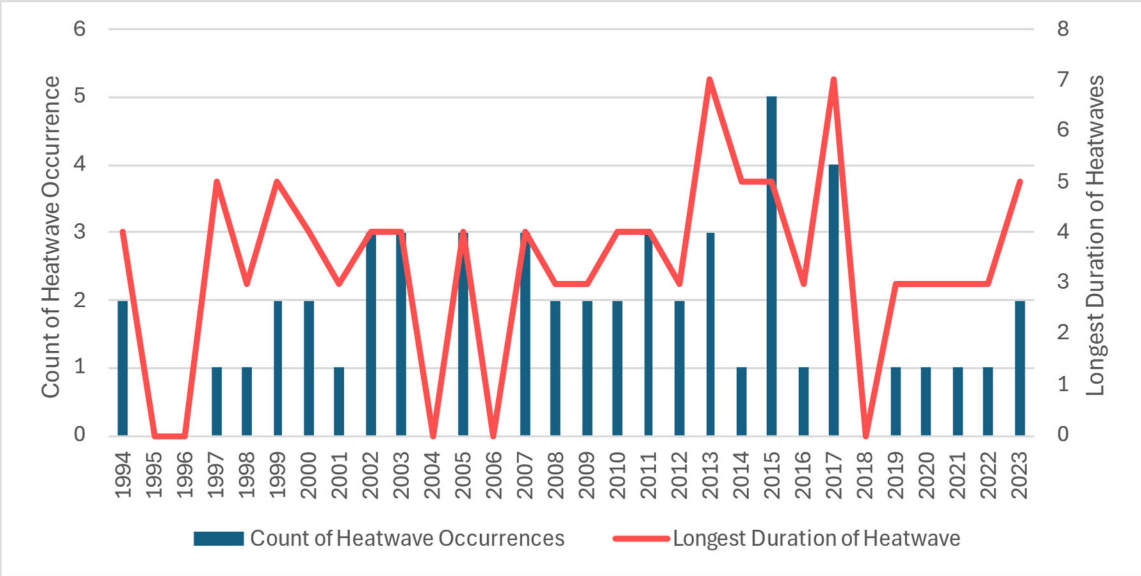


Figure 3.6 Heatwave statistics at Hobart (Ellerslie Road) (BoM Site 094029) from 1994 to 2023 including total length of heatwaves (primary axis) and the longest duration of heatwave each year (secondary axis). Here heatwaves are when both maximum and minimum temperatures are above normal (the 85th percentile of historical data).

3.1.2 Rainfall

The mean annual rainfall for Hobart (Ellerslie Road) is 611.5 mm. The BoM rain gauge at Hobart (Ellerslie Road) has been collecting rainfall data since 1882 and the highest recorded annual rainfall was 1,104.2 mm recorded in 1916 as shown in Figure 3.7. In the last 30 years (1993-2023), the average annual rainfall is 565.9 mm. The highest recorded monthly rainfall for this site was 255.4 mm in March 1946.

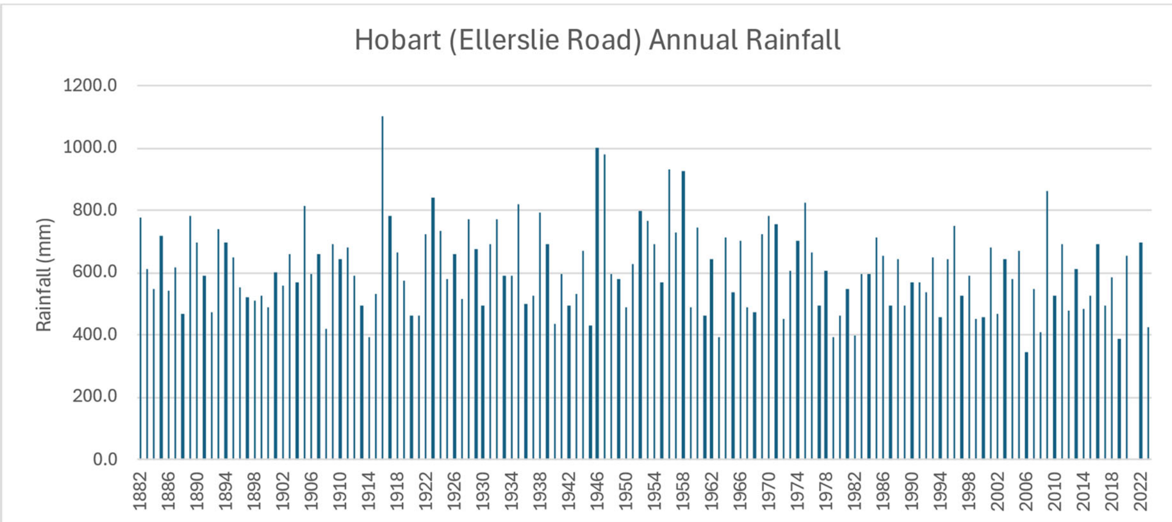


Figure 3.7 Annual rainfall from 1882 to 2023 (Hobart (Ellerslie Road) BoM Station 094029)

3.1.3 Coastal Water Levels

Present-day tide

Tides occur as a response to astronomic gravitational forces, largely due to the effects of the sun and the moon on the earth. At Hobart, the tides vary in a semi-diurnal pattern (two high, and two low tides per 24-hours) and a moderate spring/neap variation (larger tides during full and new moons). Other longer-term variations also occur that mean certain high tides are larger than others.

The theoretical highest or lowest tide that can be caused by astronomic forces alone under average meteorological conditions is known as the 'Highest Astronomical Tide' (HAT) or 'Lowest Astronomical Tide' (LAT).

The intertidal areas are defined by land with elevations between HAT and LAT. These areas do not typically contain development and are composed of beaches, estuary banks, marshes, and mangrove areas, which are largely tolerant of regular inundation. The exception is coastal-dependent development such as ports, harbours, marinas and recreational boating facilities (e.g. boat ramps).

For this project, present-day HAT at Hobart has been estimated to be 0.87 mAHD. This is based on analysis of the hourly tide gauge observations at Hobart and compares well with other recent planning developments.

Extreme sea levels

Extreme sea levels are caused by the combination of a high tide with another disturbance to the ocean that results in short-term elevated sea levels. A common driver of extreme sea levels are low pressure weather systems that can elevate sea levels through a combination of low atmospheric pressure and wind setup (that can cause water to 'pile' up against the coast). The difference between the predicted astronomic tide and the observed water level is referred to as the 'tidal anomaly' or 'storm surge' during severe weather conditions. The resultant combination of storm surge and the underlying astronomical tide is sometimes referred to as the 'storm tide'.

Open coast storm tide events are often accompanied by large ocean waves that can drive temporary increases to water levels due to breaking waves across a surf zone, known as wave setup. Macquarie Point is well protected from ocean swells, with only locally generated wind waves able to reach the shoreline during severe weather events, which do not generate significant wave setup at the location of interest. The contribution of wave setup at the Project Site is therefore assumed to be insignificant.

Several previous studies and online portals provide extreme water level statistics based on an analysis of historical data recorded by the Hobart tide gauge, including:

- Hunter (2007) *Historical and Projected Sea-Level Extremes for Hobart and Burnie*, Tasmania, prepared by the Antarctic Climate and Ecosystems Cooperative Research Centre and commissioned by the Government of Tasmania https://nre.tas.gov.au/Documents/CCCRMP-Hunter_Report.pdf

- McInnes, et al. (2011) *Climate Futures for Tasmania, Extreme Tide and Sea-Level Events,* prepared by the Antarctic Climate and Ecosystems Cooperative Research Centre https://climatefutures.org.au/technical-reports/extreme-tide-sea-level-events-technical-report/

- UWA (2018) Extreme Sea Levels in Australia, maintained by UWA and Bushfire and Natural Hazards CRC https://sealevelx.ems.uwa.edu.au/index.php

- CSIRO Canute 3 (2023) *Sea level calculator – July 2023 release*, maintained by CSIRO Climate Systems National Environmental Science Program https://shiny.csiro.au/Canute3_0/

BMT (2023) completed an independent analysis of the Hobart tide gauge observations to estimate extreme water levels. The levels produced in this assessment were generally consistent with other estimates for Hobart summarised in Table 3.1 and based on the sources listed above. It is noted that each study used differing datasets or methods, and may not be directly comparable (e.g., Hunter 2007 presents extremes in the context of exceedance likelihood in a future climate).

Table 3.1 Comparison between 1% AEP extreme sea-level estimates (m rel. MSL)

BMT	Hunter (2007)	Canute 3 CSIRO (2023)	McInnes (2012)	UWA (2018)
1.26	~1.4*	1.44	1.24	1.29
*Hunter (2007) presents the analysis results in terms of exceedance % of specific levels with a distance of 0.1m during a future climate year, and hence the level shown in this table has been estimated.				

3.2 Future Climate Projections

3.2.1 Temperature

The Australian climate is already changing, and this is clearly represented in records of observed temperatures. Figure 3.8 depicts the long-term land-based temperature record for Australia, combining data from measuring stations across the nation. This demonstrates a warming of around 1.5°C since 1910. This long-term warming trend means that most years are now warmer than almost any observed during the 20th century (BoM and CSIRO, 2022). Similar trends are also observed in Tasmania (Figure 3.9)

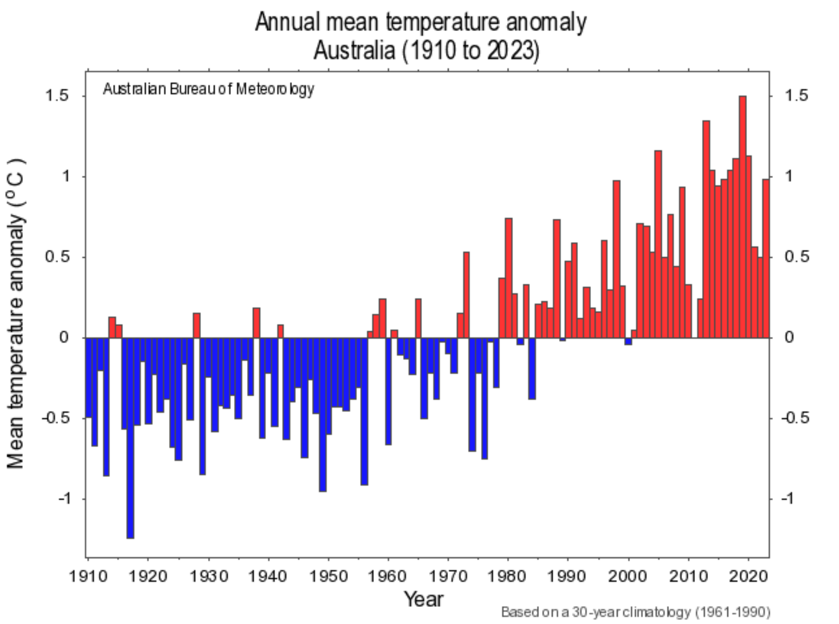


Figure 3.8 Annual Mean Temperature Anomaly for Australia (1910 – 2021)

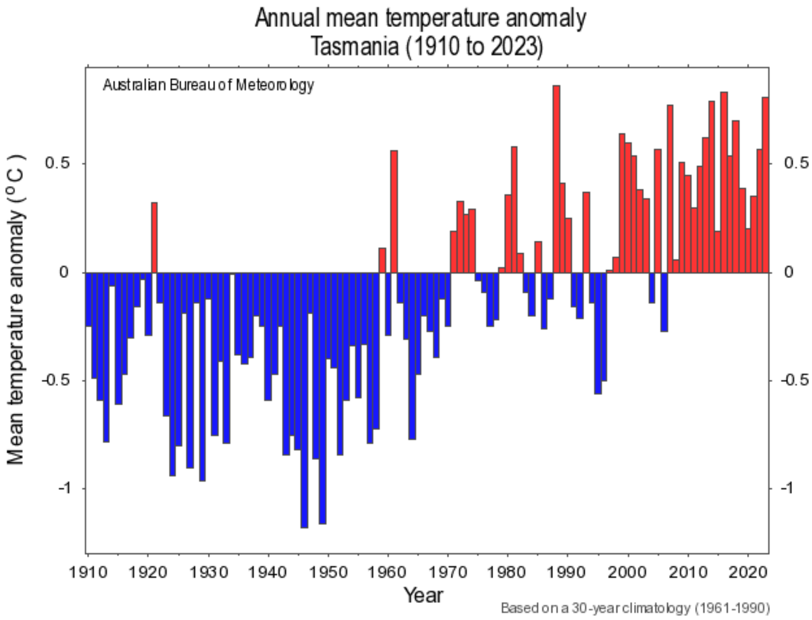


Figure 3.9 Annual Mean Temperature Anomaly for Tasmania

To assess how temperature is projected to change under future climate scenarios, climate projection datasets have been compiled and assessed from varying sources.

The Tasmanian Government has released downscaled climate projections grids that have been intersected with the Project Site to determine how future temperature is projected to change. These projections model the anticipated climate under the RCP 8.5 scenario for the years 2030 and 2050. The analysed climate projections include the risk percentage of having more than 10 days above 30°C from 1st December to 8th February for the current period, 2030, and 2050, as well as the risk percentage of having more than 3 days above 31°C from 1st January to 28th February for 2030 and 2050. These projections demonstrate that temperature and duration of high temperatures across the Project Site are projected to increase and are detailed in Section 5.1.

Climate projections released by the City of Hobart indicate that temperatures are expected to increase under a high emissions scenario. The number of extreme hot days (>40°C) is expected to increase, along with the average annual daily mean temperature, daily maximum temperature, hottest daily temperature of the year and temperature of the warmest nights by 2100. The projected changes in temperature are detailed further in Table 5.1 of Section 5.2.

The findings from the Intergovernmental Panel on Climate Change (IPCC) 6th Assessment Report (AR6) have also been summarised. Future projections from AR6 indicate that temperatures are projected to increase for Hobart. In particular, AR6 findings projected that there will be more >30°C days contributing to more warm spells on average and an increased number of heatwave days. The findings from AR6 are detailed further in Section 5.1.

3.2.2 Rainfall

Lack of rainfall is a major driver of hotter conditions. Analysis of observed rainfall over the whole of Australia shows that conditions are becoming wetter over the north of the country and drier over southern regions (BoM and CSIRO, 2022). Specifically, April to October rainfall has been declining around south-east Australia for the past two decades with fewer wet years now than there were during the 20th century (Figure 3.10). Parts of Tasmania have also received below average warm season rainfall in recent decades, with rainfall across the southeastern area of Tasmania receiving very much below the average amount of rainfall in recent years (BoM and CSIRO, 2022).

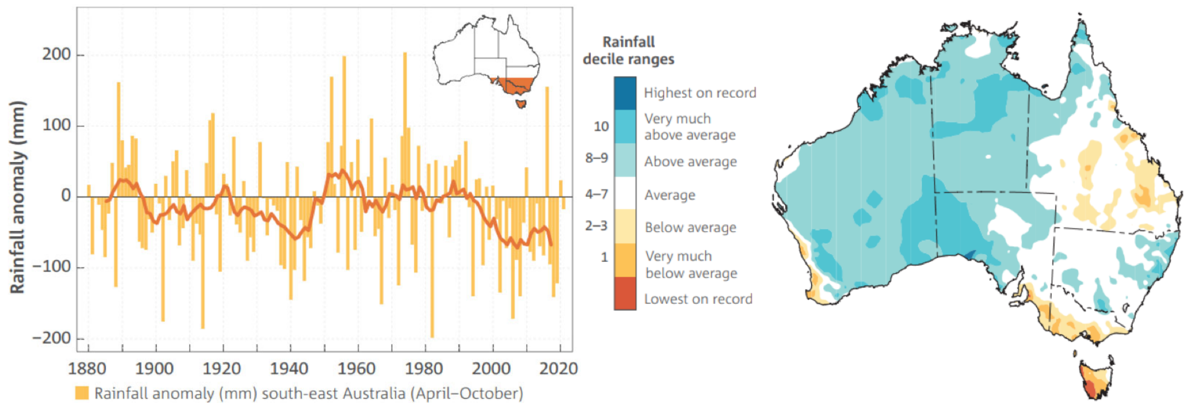


Figure 3.10 Anomalies of April to October rainfall for south-eastern Australia with 11-year running mean and 2000-2020 rainfall deciles (CSIRO and BoM, 2022)

White et al. (2016) analysed historical extreme rainfall days for Tasmania and predicted annual and seasonal changes under future a climate scenario (2070-2099). For Hobart, an increase in extreme precipitation days was predicted across all seasons with more significant increases during Autumn (Figure 3.11).

For future climate flood and overland flow assessment, Australian Rainfall and Runoff (Geoscience Australia) provides guidance on increases to rainfall intensity. The recommended increases are summarised in Table 3.2 and are considered further as part of the overland flooding hazard and risk assessment for the Project Site (reported separately).

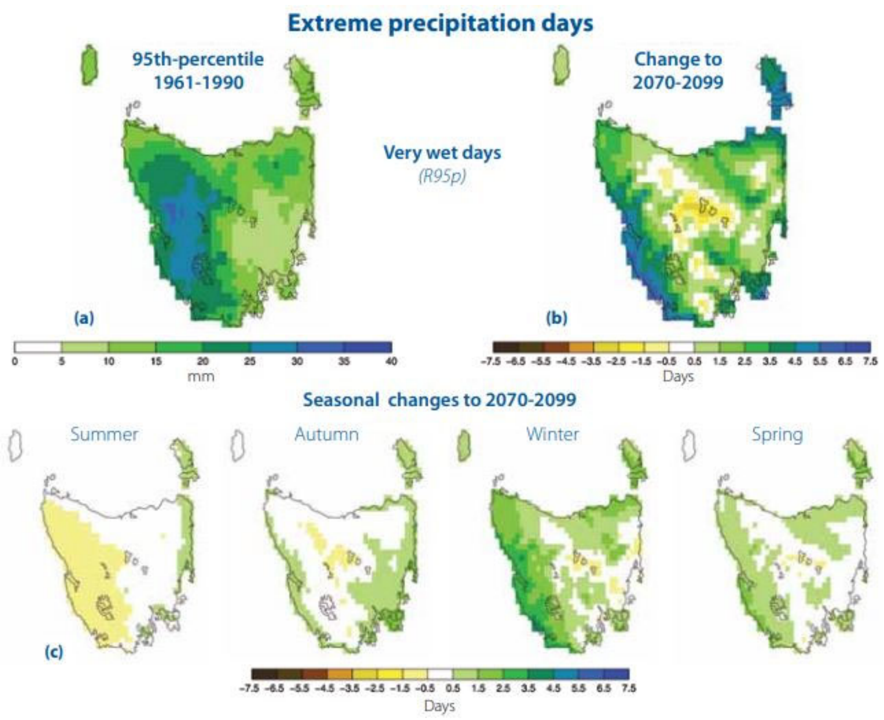


Figure 3.11 Annual and seasonal very wet days (i.e., when daily precipitation totals exceed the 95th percentile of average).

a) observed very wet days between 1961-1990 period (in mm), b) future annual projection of very wet days 2070-2099 (in days) and, c) seasonal projection of very wet days for 2070-2099 (in days). Projections are for A2 (higher) emissions scenario. (White et al. 2016)

Table 3.2 Future climate increases to rainfall intensity (https://data.arr-software.org/)

2030	0.648 (3.2%)	0.687 (3.4%)	0.811 (4.0%)
2040	0.878 (4.4%)	0.827 (4.1%)	1.084 (5.4%)
2050	1.081 (5.4%)	1.013 (5.1%)	1.446 (7.3%)
2060	1.251 (6.3%)	1.229 (6.2%)	1.862 (9.5%)
2070	1.381 (7.0%)	1.460 (7.4%)	2.298 (11.9%)
2080	1.465 (7.4%)	1.691 (8.6%)	2.719 (14.2%)
2090	1.496 (7.6%)	1.906 (9.7%)	3.090 (16.3%)

3.2.3 Coastal Water Levels

Sea level rise (SLR) will cause an increase to Mean Sea Level (MSL) and move the intertidal zone to a higher elevation, exposing low-lying coastal areas to tidal processes.

In 2021/22, the IPCC released Assessment Report 6 (AR6) which included updated sea level rise projections. AR6 presents sea level projections relative to future climate scenarios, known as SSP (shared socioeconomic pathways) scenarios, which SSP5-8.5 the most similar to the previous RCP8.5 scenario. The SSP5-8.5 projections are reported for two confidence levels, medium and low, with medium being similar to the RCP8.5 projections.

The AR6 projection based on SSP5-8.5 (medium confidence level) has been used to estimate future estimated future extreme sea-levels at Hobart. These projections, along with the other source, are shown in Table 3.3. The estimated and future climate HAT tide level is provided in Table 3.4.

Table 3.3 Sea level rise projections for Hobart

Year	Hobart Sea Level Rise Projection (CSIRO, 2016) m	AR6 SSP5-8.5 Medium Confidence m	AR6 SSP5-8.5 Low Confidence m
Present (~2020)	-	0.05	0.06
2050	0.23	0.23	0.24
2070	-	0.40	0.43
2100	0.85	0.78	0.89
2120	-	1.01	1.26

Table 3.4 Future HAT levels (mAHD) based on AR6 SSP5-8.8

Year	Sea level rise m (SSP5-8.5 Medium Confidence)	Future HAT level mAHD
Present	0.05	0.87
2050	0.23	1.05
2070	0.40	1.22
2100	0.78	1.6
2120	1.01	1.83

The 1% AEP extreme sea-level estimated by BMT (2023) and provided in Table 3.1 (1.26 mMSL) has been extended to incorporate sea level rise based on the AR6 SSP5-8.5 Medium Confidence projections in Table 3.4. The outcome of this simple analysis is provided in Table 3.5, noting that further assessment of coastal inundation risks at the Project Site under current and future climates are reported separately.

Table 3.5 Future 1% AEP extreme sea-level considering AR6 SSP5-8.8

Year	Sea level rise m (SSP5-8.5 Medium Confidence)	Future 1% AEP mMSL
Present	0.05	1.31
2050	0.23	1.49
2070	0.40	1.66
2100	0.78	2.04
2120	1.01	2.27

4 Heat Assessment: Mapping of Urban Heat Island

4.1 Heat Risk and Heatwave

Heat is a significant challenge facing Australian communities of all sizes, particularly as the effects of climate change are already being felt and are projected to continue to intensify into the future. Over time, there is high confidence that climate change will lead to more frequent and hotter days across Australia, with the average temperature projected to increase by +1.1°C by 2041-2060 under SSP2-4.5 or +1.5°C under SSP5-8.5, and by +1.9°C by 2081-2100 under SSP2-4.5 or +3.7°C under SSP5-8.5 (Calvin et al., 2023). Despite this, measures to address heat pressures within planning frameworks and building codes are lacking. Responses have generally focused on managing the issue during heatwaves or leading into a heatwave event.

Heat hazard can be a challenge anywhere a heatwave event occurs. However, risk from extreme heat events are particularly challenging in urban areas due to the Urban Heat Island (UHI) effect. UHI effect is caused by altering natural surfaces to anthropogenic surfaces and land uses where the form, function and heat-trapping materials of the built environment absorb more heat and reduce permeability (and therefore surface moisture). This results in making urban areas hotter than surrounding rural and natural landscapes, impacting air quality, energy consumption and human health and morality. Regardless of this, the desire to live in cities and urban centres is increasing. Consequently, it is imperative that heat management is addressed through planning, design and construction of cities, neighbourhoods, and major infrastructure projects to help mitigate the built environment’s impact on the UHI effect and assist people in adapting to a warming climate.

4.2 Urban Heat Islands

Urban built-up areas are susceptible to the UHI effect, where temperatures are typically higher than in surrounding rural and natural areas. Factors such as the removal of trees, expansion of impervious surfaces and use of heat-trapping materials (like dark coloured roofs, bitumen pavements and cladding) contribute to increased surface temperatures. The obstruction of wind airflow from reduced building separation, larger buildings on smaller lots, and lack of tree canopy can further raise temperatures in urban areas.

Cities, towns, and urban areas amplify the impacts of a warming climate and the intensity of severe and extreme heatwaves because of the UHI effect. The UHI effect can also vary within urban areas, with some areas being hotter and having higher heat severity. This largely depends on the built form of an urban area, extent of natural ground surfaces, tree canopy, use of materials (with dark pavement and roofing absorbing more heat) and topography. The extent of these differences also varies with weather conditions, season, and time of day, often being most pronounced at night. In high density areas, temperatures can be particularly high since the weather conditions associated with heatwave events (i.e. low wind speeds and cloud-free conditions), also favour the development of the UHI effect.

The UHI may benefit urban residents in winter, but also increases the likelihood of heat-related illness and death in summer. In the context of a warming climate and a projected increase in the frequency, intensity, and length of heatwaves with climate change, exposure to heat risks is more pronounced for people living in cities and urban areas because of the UHI effect. These risks can significantly increase for communities in already hot or humid climates and for people living in cooler climates, where built environments were not historically planned or designed for increased temperatures under climate change.

4.3 Air Temperature

Air temperature from the BoM station located at Hobart (Ellerslie Road) was collected and analysed to understand general temperature trends relevant to Project Site. Figure 4.1 shows the daily maximum temperature from 1942 to 2023. Within Australia, the summer of 2018/2019 was one of the hottest on record, a trend also observed in Hobart. The maximum daily air temperature recorded during this period was 40.8°C on the 30th of December 2018, followed by 40.4°C on the 31st January 2019.

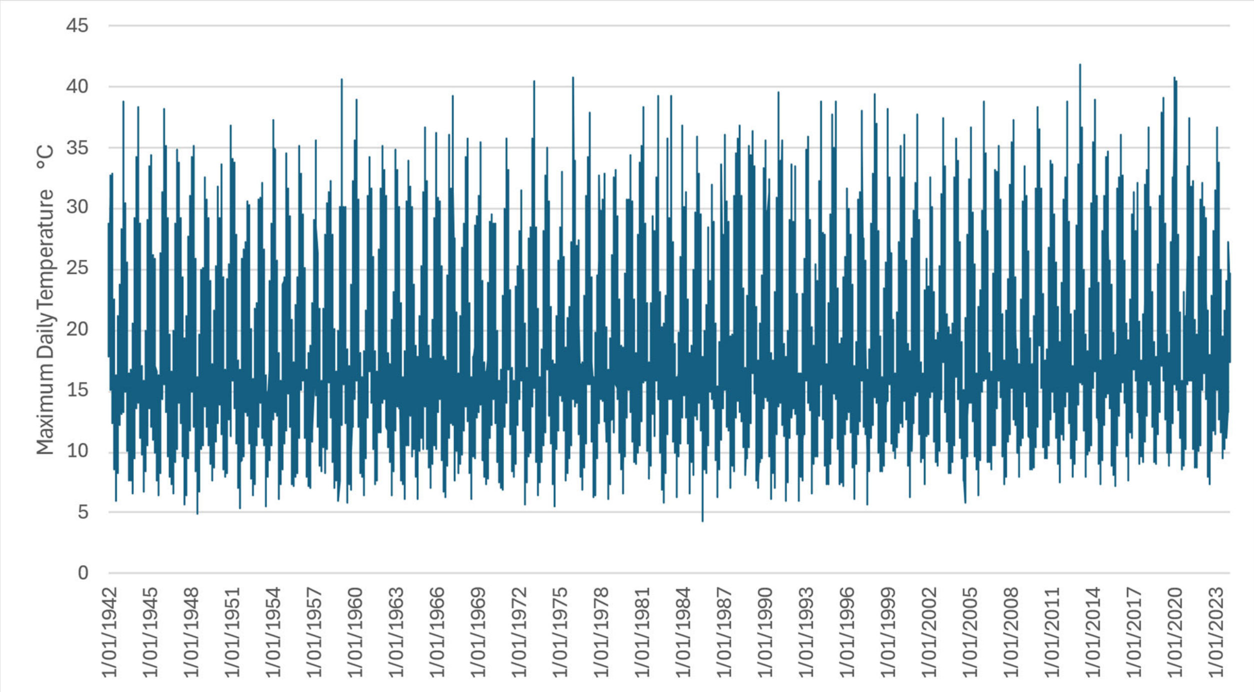


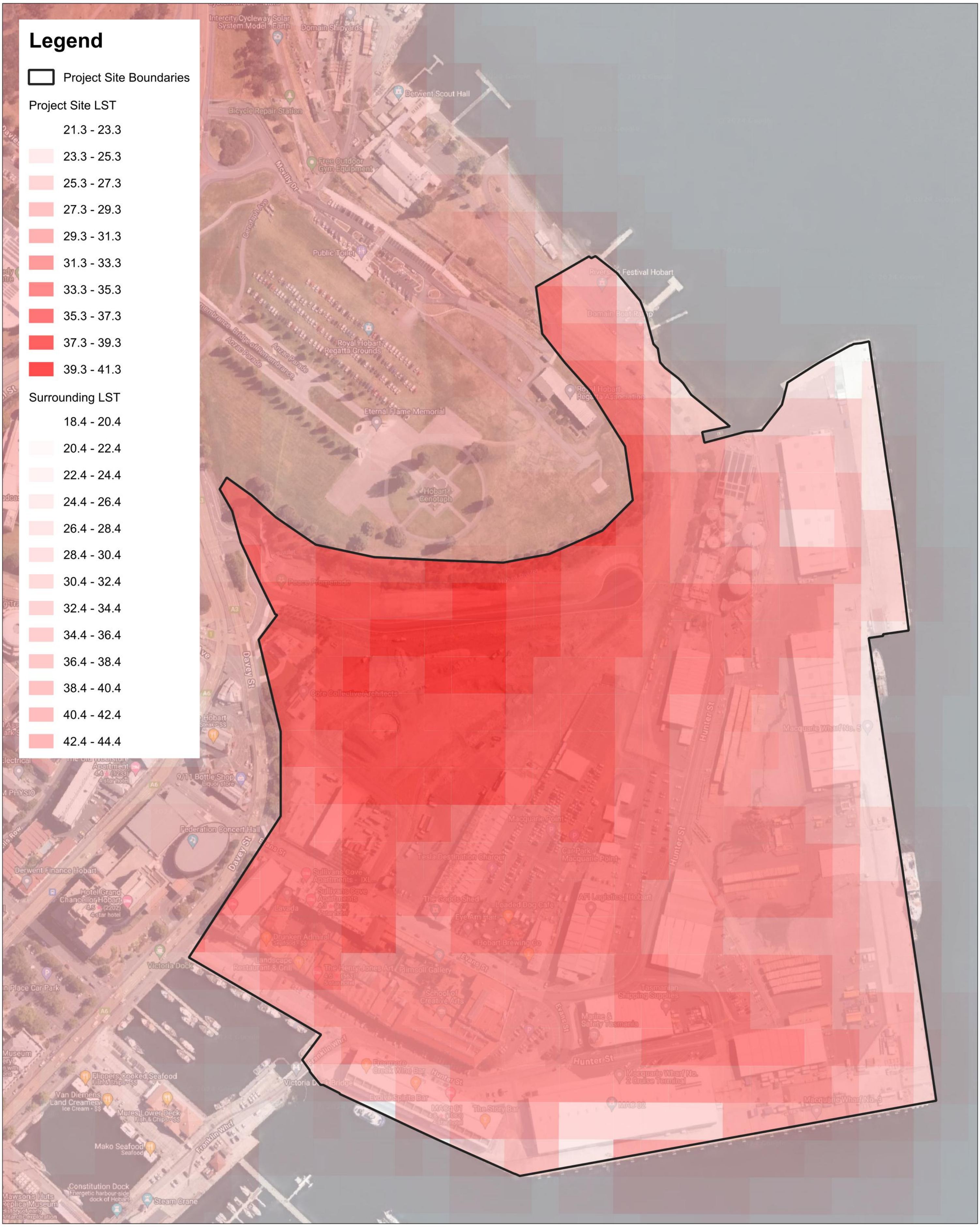
Figure 4.1 Maximum daily temperature at Hobart (Ellerslie Road) (BoM Station 094029)

Therefore, despite not being the most recent summer, the 2018/2019 summer (November 2018 to March 2019) was selected for analysis of UHI as is the hottest contemporary summer.

4.4 Estimating Urban Heat Island (UHI)

To identify areas which have relatively elevated temperatures across the Project Site, the Land Surface Temperature (LST) of the Project Site were estimated using thermal bands of 30m-by-30m resolution Landsat-8 imagery following best practice approaches (Du et al., 2015). The hot summer of 2018/2019 (from 1st November 2018 to 31st March 2019) was used to analyse the maximum UHI effect on the Project Site.

This LST for the Project Site and surrounding area over the 2018/2019 summer is shown in Figure 4.2. The LST varies across the site, with cooler areas predominantly adjacent to the harbour, where temperatures range between 21.6°C and 31.6°C. Temperatures are lower in the northeast corner and gradually become warmer towards the southward, closer to the Macquarie Wharf No. 3 and areas adjacent to Constitution Dock. The hotter areas steadily become more concentrated from the interior westward with temperatures ranging from 34.2°C to 40.3°C.



Title:
Project Site Land Surface Temperature (November 2018 - March 2019)

Figure: 4.2

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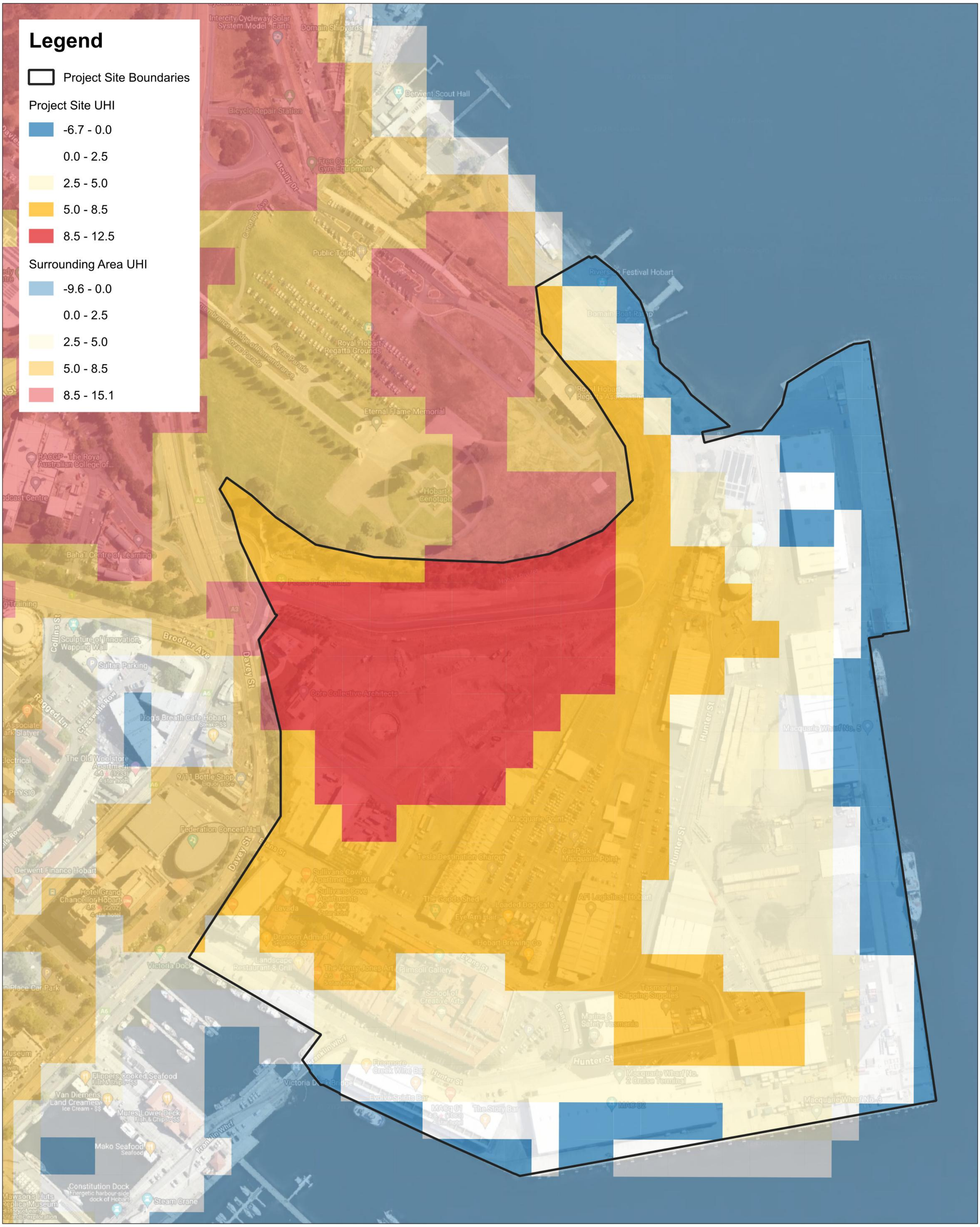
To identify the UHI effect relevant to the Project Site, the Land Surface Temperature (LST) of urbanised areas are compared to the LST of non-urban areas. An UHI index is created by calculating the difference between urban and nearby rural reference areas (Jin, 2012; Marcel and Villot, 2021). The LST of the Knocklofty Reserve was selected as the baseline temperature of non-built-up areas as this is a large area of dense vegetation within the region. It was found that the mean LST for the Knocklofty Reserve for the summer of 2018/2019 was 27.9°C. This temperature was then subtracted from the LST of each cell of the satellite image to determine the UHI factor of a given cell.

4.5 UHI Exposure of the Project Site

The UHI hotspots relevant to the Project Site were mapped as shown in Figure 4.3. Similarly to Figure 4.2, the major hotspots of the Project Site are predominately concentrated to the north west of the Project Site, south of the Anzac Parade. This area is primarily characterised by bare gravel, roads and black asphalt, as well as moderate to minimal areas of vegetated corridors separating Anzac Parade and Davey Street from the Project Site. Areas with a lower UHI are concentrated to the eastern and southern boundaries of the Project Site, closest to the River Derwent. This likely exposes built elements to the natural cooling function of the river and winds which are naturally cooled by a large water body of the River Derwent.



Title:

Project Site Urban Heat Island Hotspots

Figure: **4.3**

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4.6 Surface Types

UHI effect can be further exacerbated by built and natural environmental factors. To understand how the UHI of the Project Site is distributed, site information detailing surface types was compiled from multiple sources (Council, commercial and opensource GIS data, Sentinel-2 bands, and aerial imagery). Information such as building type, building materials, road and pavement material, vegetation types and paved surface categories were collated and analysed.

Along with natural surfaces and elements such as soil, grass and trees, three major construction materials have been used at the current site. They are Steel, Concrete, and Asphalt or Bitumen.

Surface type heavily influences UHI and is dependent on the materials reflectivity. Reflectivity is measured is measured by albedo and determines the extent that solar radiation will be reflected (or absorbed) by the surface. Table 4.1 describes the reflectivity characteristics of difference surfaces identified where the following definitions apply:

- Albedo: a measure of the light reflected from a surface. This quantity ranges from zero to one where zero is a black surface that absorbs all light and one is a white surface that reflects all light. Higher albedo of a surface suggests higher reflectivity which can result in less absorption of sunlight by the surface resulting is less heat gain.
- Emissivity: a measure of how quickly/efficiently a surface emits (releases) absorbed heat to return to its normal temperature. This measure ranges from zero to one where a value of one means that the surface is radiating the heat at the same rate that it is absorbing it. Typically, more reflective objects have lower emissivity.

Table 4.1 Surface characteristics (Santamouris, 2016; Sharma et al., 2016; Zhang, Fukuda and Liu, 2019; Bherwani, Singh and Kumar, 2020; BlueScope, 2020; He et al., 2020; Pfautsch and Wujeska-Klause, 2021)

Surface type	Albedo	Emissivity	Interpretation
Asphalt pavement	0.1	0.9	Asphalt does not reflect a large portion of solar energy and also holds heat for longer compared to other materials such as Steel.
Concrete roof and pavement	0.4	0.9	Concrete has a moderate ability to reflect solar energy and holds heat for longer compared to other materials such as Steel.
Steel roof and wall	0.5	0.2	Steel has a moderate ability to reflect solar energy but does not hold heat as long as concrete or Asphalt as it transfers heat quickly.
Tile (roof)	0.2	0.9	Tile rooves have a low reflectivity of solar energy but can hold heat for longer compared to other materials such as Steel.
Bare Soil	0.2	0.98	Bare soil does not reflect a large portion of solar energy and holds it for longer.
Grass	0.2	0.3	Grass has low reflectivity of solar energy but does not hold heat for long.
Shrubs	0.2	0.3	Shrubs has low reflectivity of solar energy but does not hold heat for long.

Analysis of the Project Site found that the paved surfaces were the predominate surface type accounting for 54% of landcover as seen in Figure 4.4. This followed by built-up (21%), soil (19%) and then vegetation (5%).

As observed in Figure 4.2 and Figure 4.3, areas with the hottest UHI and LST correlate with the soil and paved surface types. This is due to the low to moderate albedo and emissivity of these surface types, implying that these surface types have low reflectivity of solar energy and will hold heat for longer. Bare soil typically has very high surface temperature values due to low albedo (absorbs most of the heat coming from the sun). Similarly, older buildings developed pre 1980 (before construction regulations) were built under different building codes and therefore may not include heat measures included in modern building codes.

Title:

Project Site Surface Types

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Figure 4.4 depicts the estimated average UHI for various surface types relative to the baseline (Knocklofty Reserve). It shows that soil surfaces, comprising of gravel and bare soil, exhibited the most pronounced UHI effect, with a maximum average of 8.6°C higher than the baseline. This is likely due to the high heat absorption and slow emissivity of bare soils and gravel. Paved surfaces, largely comprising of asphalt or bitumen and concrete, followed closely with a maximum average UHI of 4.8°C, as expected due to their dark, heat-trapping nature.

The ranking then deviates from typical expectations. Vegetation surface types exhibited a maximum average UHI of 4.6°C, while built-up areas had a maximum average UHI of 4.5°C. While vegetation is often associated with shade and passive cooling, the Project Site's vegetation primarily consists of grass patches bordering footpaths and roads, along with exposed bare soil. In this context, these vegetation surface types would absorb heat rather than providing shade and contributes to a higher UHI.

Conversely, the built-up areas, comprising of tile roofs and steel structures, may benefit from their proximity to the River Derwent, having served as storage areas and industrial sheds prior to shipping. The outward orientation towards the river and the potential channelling of wind in a north-westerly direction from the river mouth could influence the UHI of these areas. Additionally, the emissivity of these structures might further contribute to a lower UHI compared to vegetation as well as the white roofing increasing albedo.

This highlights the importance of considering both material properties and site-specific factors when evaluating UHI intensity.

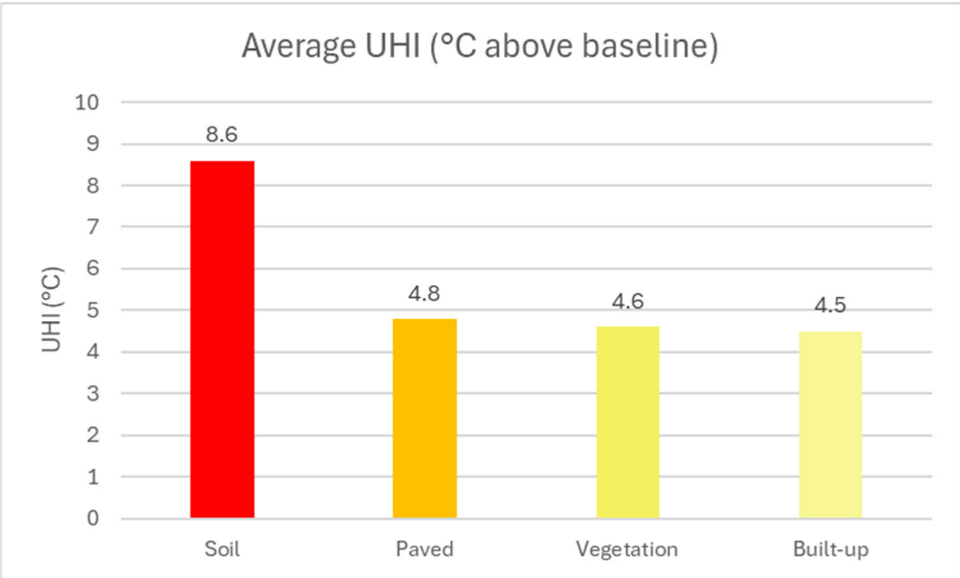


Figure 4.5 Distribution of UHI across difference surface types

5 Heat Assessment: Current & Future Climate

Climate change is likely to increase heatwave risk across Hobart with an increase in hot days projected for Tasmania as well as influence sea level rise and rainfall. This section presents how key climate variables which influence heatwave probability and frequency have been changing in the recent past and are likely to continue changing in the future. The section shall also present how climate change is likely to influence rainfall variability and implications of sea level rise.

5.1 Project Site Climate Change Projections

Climate projection datasets published by the Tasmania government have been intersected with the Project Site and analysed. These projections simulate a projected climate according to the RCP 8.5 scenario for years 2030 and 2050. Climate change projections collated and analysed are:

- Risk (%) of having more than 10 days >30°C for period 1st Dec to 28th Feb (Current, 2030, 2050); and
- Risk (%) of having >3 days of >31°C for period 1st Jan to 28th Feb (2030, 2050).

It is noted that projections made publicly available by the Tasmania Government simulate projections under a RCP 8.5. At the time of writing, there were no RCP 4.5 projections publicly available or suitable for assessing the Project Site.

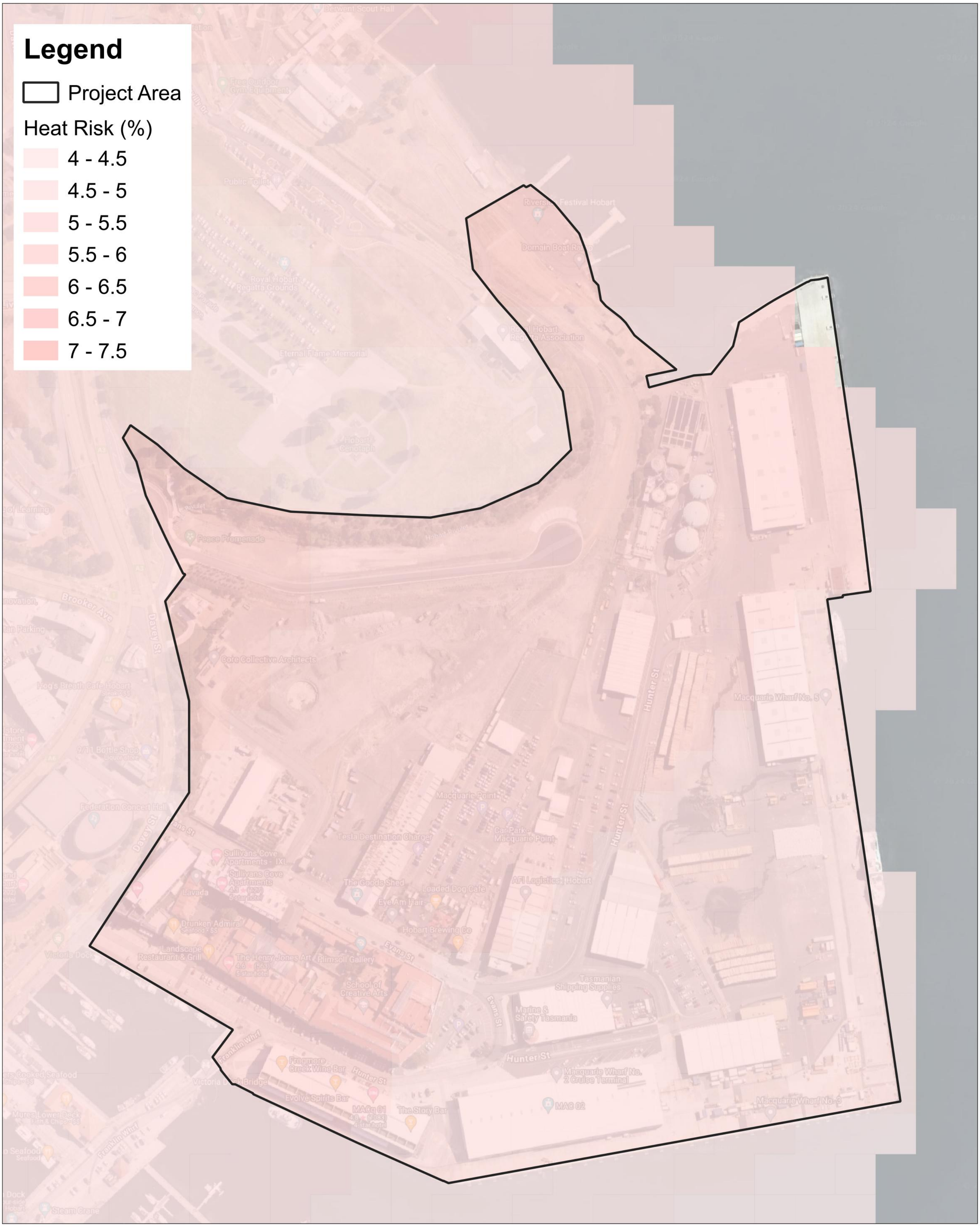
Risk of Experiencing More Than 10 Days with Temperatures Exceeding 30°C Between 1st December and 28th February

The current annual probability of 10 or more days experiencing over 30°C between December and February varies across the Project Site. The prevailing risk probability is 5 to 5.5% and is concentrated in the interior of the Project Site as shown in Figure 5.1. This risk increases progressively from the riverfront towards the west and northwest due to the moderating influence of the River Derwent. The western and northwestern have the highest probability, ranging from of 5.5 to 6%, while the riverfront area experiences a lower risk of 4 to 4.5%. Since 1990, there have been four historical occurrences where 10 or more days between December and February have exceeded 30°C being in 1994/1995, 2011/2012, 2018/2019 and 2019/2020.

Under a high emissions scenario, this risk is expected to rise significantly by 2030 as shown in Figure 5.2. The spatial pattern remains similar to the current situation. The prevailing risk probability across the Project Site is projected to be 13.5% to 14%, representing an increase of approximately 8.5 percentage points compared to the current situation. The west and northwest will experience the highest risk, with a probability of 14% to 14.5%, a rise of roughly 8.5 percentage points. The riverfront area will see the lowest increase, with a projected probability risk of 12.5% to 13.5%, which is still an increase of 8.5 percentage points.

By 2050, the probability of experiencing 10 or more hot days (exceeding 30°C) increases substantially compared to the current day. The spatial distribution again follows the current pattern (Figure 5.3). The prevailing risk probability across the Project Site is projected to be 25.5% to 26%, a significant increase of approximately 20.5 to 21 percentage points from the current situation and an additional 12 percentage points from 2030. Similar to the current situation, the west and northwest will experience the highest risk, with a probability of 26% to 26.5%, representing an increase of about 12 percentage points. The riverfront area will see the lowest risk of 24.5% to 25%, which is still an increase of 12 percentage points from the current day.

These projections highlight a substantial increase in the risk of experiencing extended hot periods (10 days or more exceeding 30°C) between December and February across the Project Site by 2030 and 2050 under a high emissions scenario. This trend aligns with anticipated rise in heatwave events across the Hobart region.



Title:

Current Heat Risk (%) of having more than 10 days of more than 30°C (Dec-Feb)

Figure: 5.1

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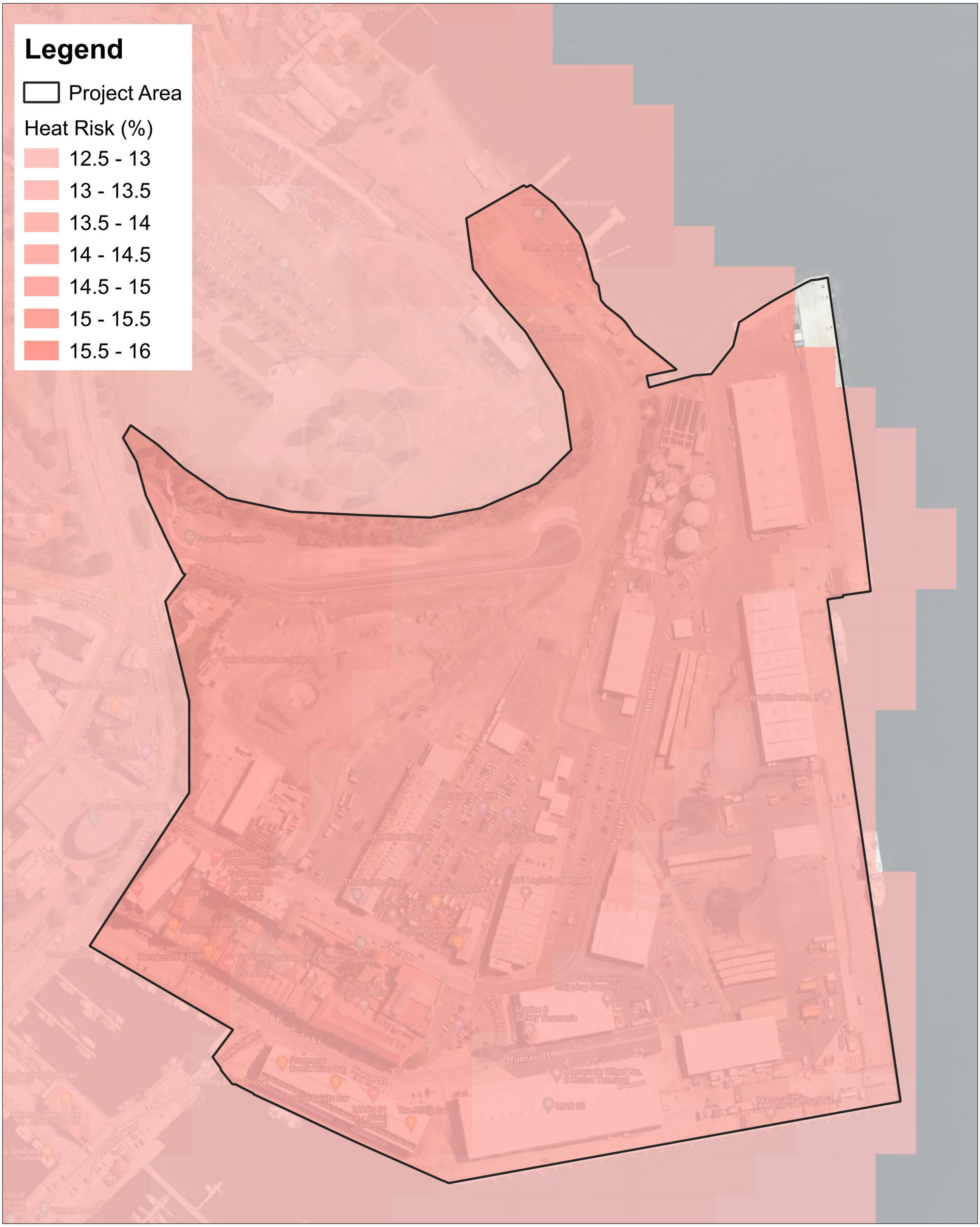

Title:

Heat Risk (%) of having more than 10 days of more than 30°C by 2030 (Dec-Feb)

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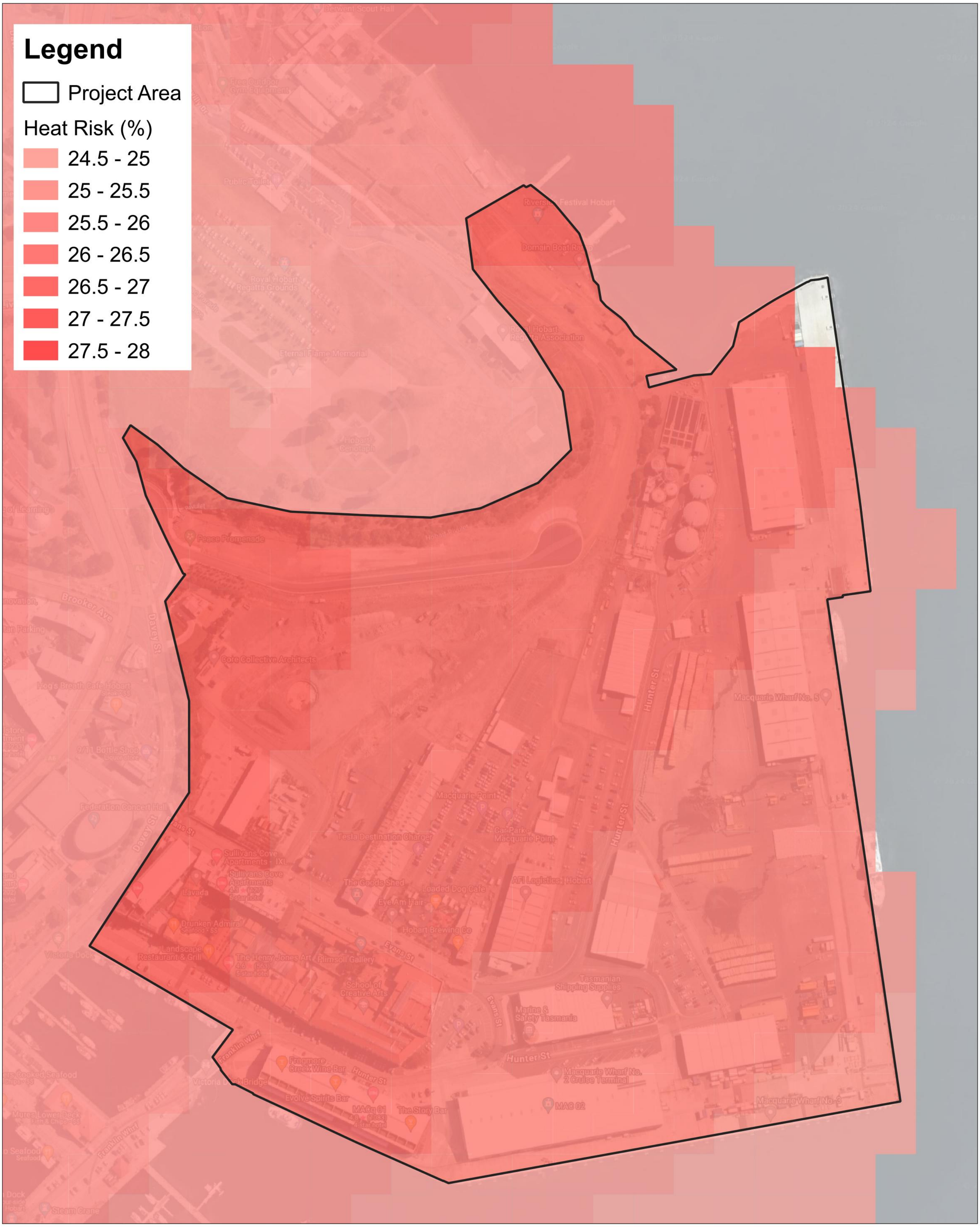

Title:

Heat Risk (%) of having more than 10 days of more than 30°C by 2050 (Dec-Feb)

Figure: 5.3

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Risk of Having More Than 3 Days of 31°C or More Between 1st January and 28th February

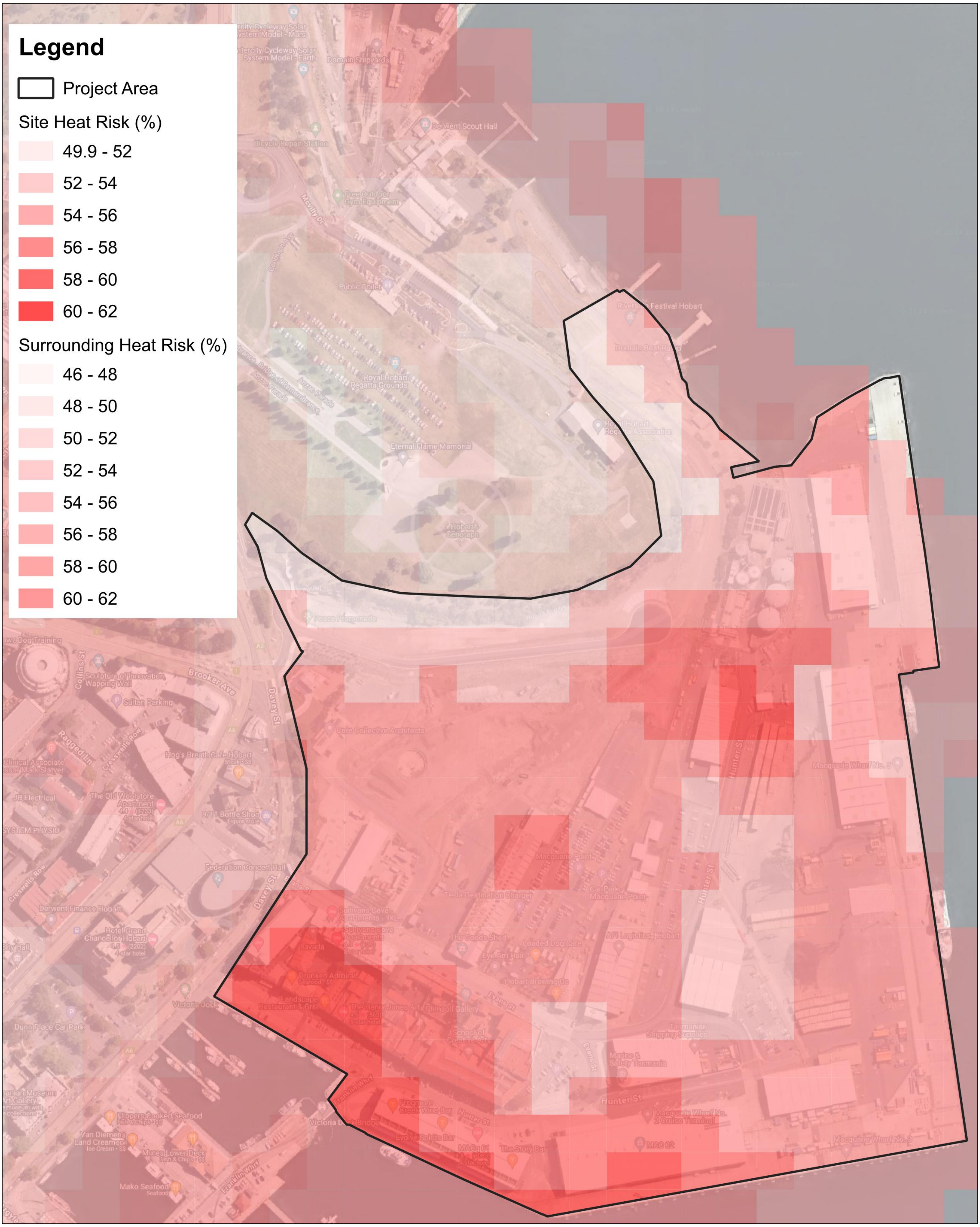
Since 1990, 22 of the 33 years had occurrences where there were three or more days where temperatures were 31°C or more. There were seven occurrences in both 2012 and 2017, and six occurrences in 2023. These three years correlate with periods experiencing heatwave events as demonstrates in Figure 3.6.

Under a high emissions scenario, the average probability of experiencing more than 3 days of 31°C or higher between January and February across the Project Site is projected to be 54.9% by 2030. As illustrated in Figure 5.4, the interior and southeastern areas bordering the River Derwent have a higher probability, ranging from 54% to 56%. Notably, the areas behind Macquarie Wharf No.5, within the Macquarie Point Carpark, and southwest of Hunter Street facing Sullivans Cove have the highest risk, with a probability of 56% to 62%. Conversely, the northern portion of the Project Site, near the Hobart Cenotaph and the northeast loading dock and shed, has the lower risk, ranging from 49.9% to 54%.

By 2050, the average probability across the Project Site is projected to increase 60%, representing a substantial rise from 2030 (Figure 5.5). The spatial distribution remains similar to the 2030 scenario with increases to areas representing a higher risk. The prevailing probability across the Project Site is expected to be 58% to 60%, concentrated in the interior of the Project Site with a notable expansion eastward bordering the River Derwent. This represents an increase of 2 to 4 percentage points compared to 2030. Similarly, the higher probability areas, now ranging from 60% to 64%, have expanded to encompass more of the interior and southern portions of the Project Site, reflecting a 4 percentage point increase from 2030. The areas of lower probability are similar to the 2030 scenario, yet contracted in near the Hobart Cenotaph, ranging from 54% to 58%, an increase of 4.1 percentage points.

The areas projected to experience more than 3 days of 31°C or more in 2030 and 2050 exhibit a strong correlation with the findings from LST (Figure 4.2), UHI hotspots (Figure 4.3) and landcover (Figure 4.4) maps. As observed in these earlier figures, elevated temperature profiles and hotspots concentrated in the Project Site's interior correspond to landcover dominated by bare soil or gravel. This trend is reflected in 2030 and 2050 projections, where areas with a higher probability of experiencing more than 3 days of 31°C or more align with these landcover types. The one exception is the southwestern area facing Constitution Dock. Here, the proximity to the River Derwent likely moderates land surface temperature, despite the surrounding landcover and projected risk probability.

These projections highlight a gradual increase in the risk of experiencing extended periods of high temperatures (more than 3 days of 31°C or more) between January and February across the Project Site by 2030 and 2050 under a high emissions scenario. This trend aligns with the anticipated potential rise in heatwave events (as discussed previous discussed) given a heatwave is defined by three consecutive days where both the minimum and maximum temperature values exceed the 85th percentile of historical temperatures for that day.



Title:

Heat Risk (%) of having >3 days of >31°C by 2030 (Jan-Feb)

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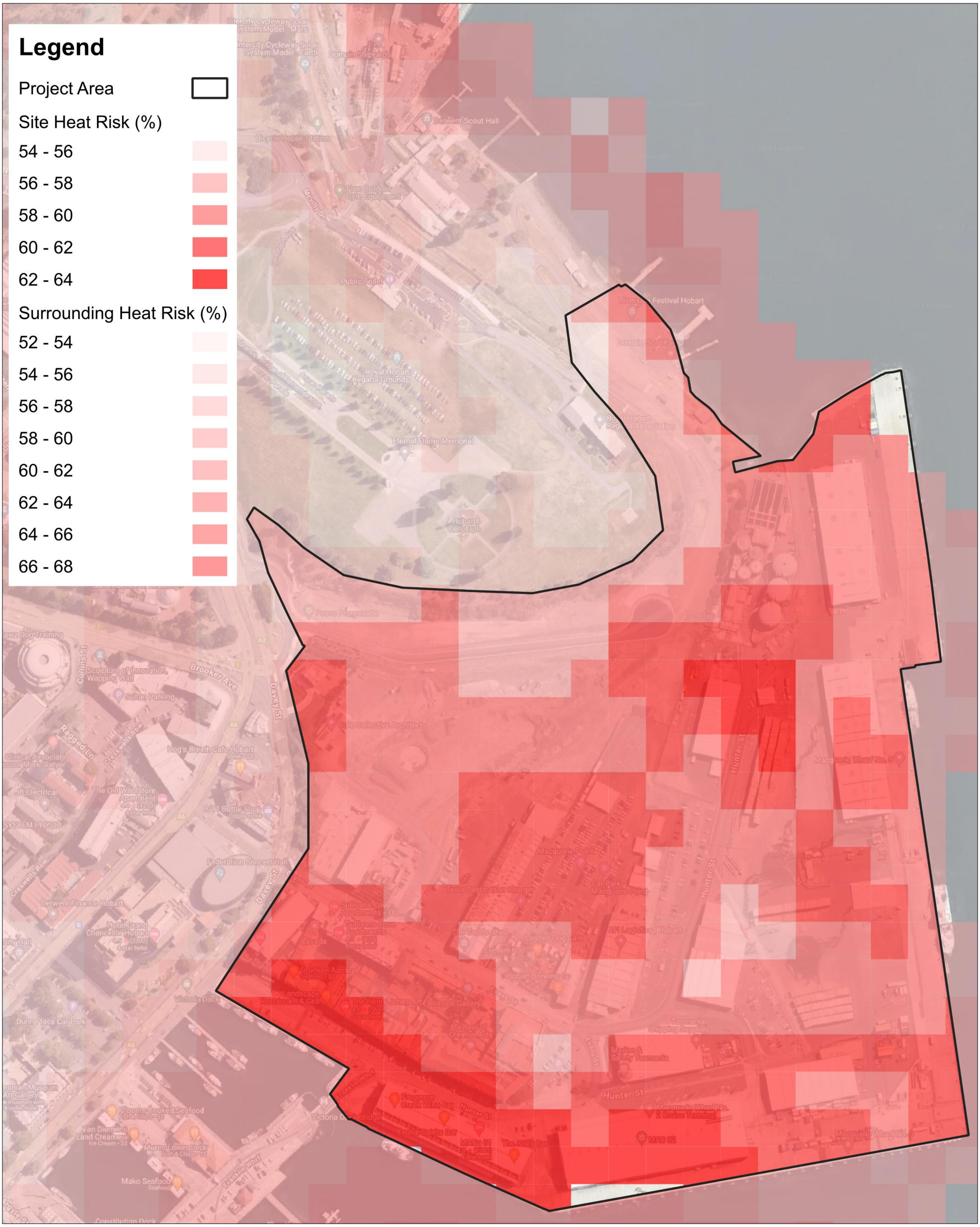

Title:

Heat Risk (%) of having >3 days of >31°C by 2050 (Jan-Feb)

Figure: 5.5

Rev: A

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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5.2 Projected Climate Change in Hobart

5.2.1 City of Hobart Supported Climate Change Projections

In accordance with the climate projections supported by the City of Hobart, the number of extreme hot days (>40°C) is expected to rise. The frequency of heatwaves is projected to remain stable but with increased intensity (warmer days and nights) (T.A. Remenyi et al., 2020). Under a high emissions scenario, average annual daily mean, daily maximum temperature, hottest daily temperature of the year, temperature of warmest days and warmest nights, average summer days (>25°C) and average annual hot days (>30°C) are projected to incrementally increase by 2100. Further, there are projected variations in the average annual rainfall, seasonal rainfall, and annual maximum daily rainfall are leading to 2100. Table 5.1 details the projected changes across the 2040, 2060, 2080 and 2100 timeframes.

Table 5.1 City of Hobart RCP 8.5 Emission Scenarios

Climate Variable	1961-1990 value	2021-2040 value	2041-2060 value	2061-2080 value	2081-2100 value
Average annual daily mean (°C)	11.9°C	12.9°C	13.5°C	14.2°C	14.8°C
Average daily maximum temperature (°C)	16.8°C	17.8°C	18.5°C	19.2°C	19.7°C
Hottest daily temperature of the year (°C)	35°C	36.3°C	37.5°C	38.1°C	38.7°C
Temperature of warmest days [99th percentile] (°C)	30.9°C	32.1°C	33.2°C	34.3°C	34.5°C
Temperature of warmest nights [99th percentile] (°C)	15.7°C	16.5°C	16.9°C	17.5°C	17.8°C
Average annual summer days (>25°C)	18 days	22 days	25 days	29 days	32 days
Average annual hot days (>30°C)	6 days	8 days	10 days	12 days	14 days
Average annual rainfall (mm)	561 mm	549 mm	554 mm	553 mm	563 mm
Seasonal rainfall - Winter (mm)	150 mm	134 mm	141 mm	141 mm	152 mm
Seasonal rainfall - Spring (mm)	141 mm	136 mm	130 mm	129 mm	113 mm
Seasonal rainfall - Summer (mm)	139 mm	156 mm	144 mm	142 mm	154 mm
Seasonal rainfall - Autumn (mm)	141 mm	136 mm	142 mm	133 mm	151 mm
Annual maximum daily rainfall (mm)	77 mm	88 mm	81 mm	79 mm	92 mm

International and Australian experiences show that prolonged hot days increase the incident of illness and mortality – particularly among vulnerable population groups such as people who are older, have a preexisting medical condition or have a disability.

Conditions where the number of days over 30°C are projected to increase. On average between 1981 and 2010, there has been 4.5 days with such conditions. Under a high emissions scenario (RCP 8.5) this is likely to increase to 6, 8, 11 and 15 days by 2030, 2050, 2070 and 2090 (Figure 5.6).

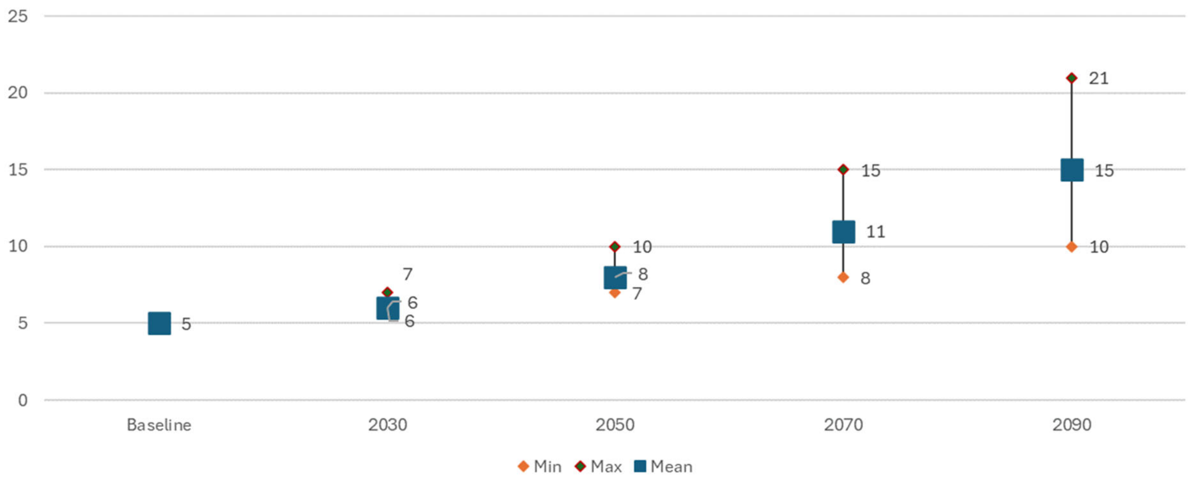


Figure 5.6 Annual average number of days over 30°C in Hobart under RCP 8.5

For example, in 2050, there can be up to 10 days annually where temperatures can be over 30°C. Source: Climate Change in Australia, Threshold Calculator by CSIRO.

Conditions where the number of annual very wet days greater than the historic 99.9th percentile is projected to slightly increase for Hobart. On average between 1981 and 2010, there has been 0.45 very wet days annually. Under a high emissions scenario (RCP 8.5), this projected to slightly increase from 2030 to 2090. As demonstrated in Figure 5.7, the number of very wet days is projected to slightly increase by 2030 from 0.45 days to 0.54 days, before slightly dropping by 2050 to then steadily increasing in 2070 and 2090 to 0.71 days.

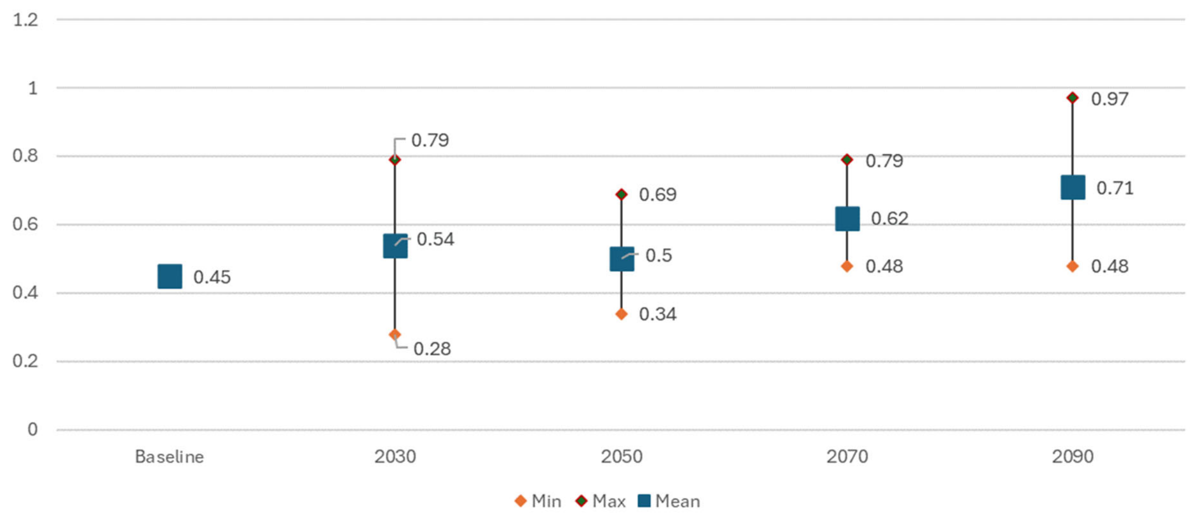


Figure 5.7 Annual average of very wet days in Hobart under RCP 8.5. Source: Climate Change in Australia, Threshold Calculator by CSIRO

5.1 Future Projected Change Based on Latest IPCC Report – AR6

The Intergovernmental Panel on Climate Change (IPCC) released its 6th Assessment Report (AR6) in 2021 which provides the most up to date understanding of our climate system and its future projections. The previous IPCC report, 5th Assessment Report (AR5) released in 2014, reported climate projections from the Climate Modelling Intercomparison Project Phase (CMIP5). Future projections in AR6 are reported based on a new generation of Climate Modelling, the Climate Modelling Intercomparison Project Phase 6 (CMIP6). These new CMIP6 models better represent the impact of large-scale climate drivers on rainfall, including dynamic sea level considerations, and better simulate extreme heat events in the atmosphere and oceans.

In AR6 climate projections are reported using a new set of scenarios called Shared Socio-Economic Pathways (SSPs), where are consistent with the previous generation of IPCC adopted Representative Concentration Pathways (RCP) scenarios, with an addition of social narratives to them.

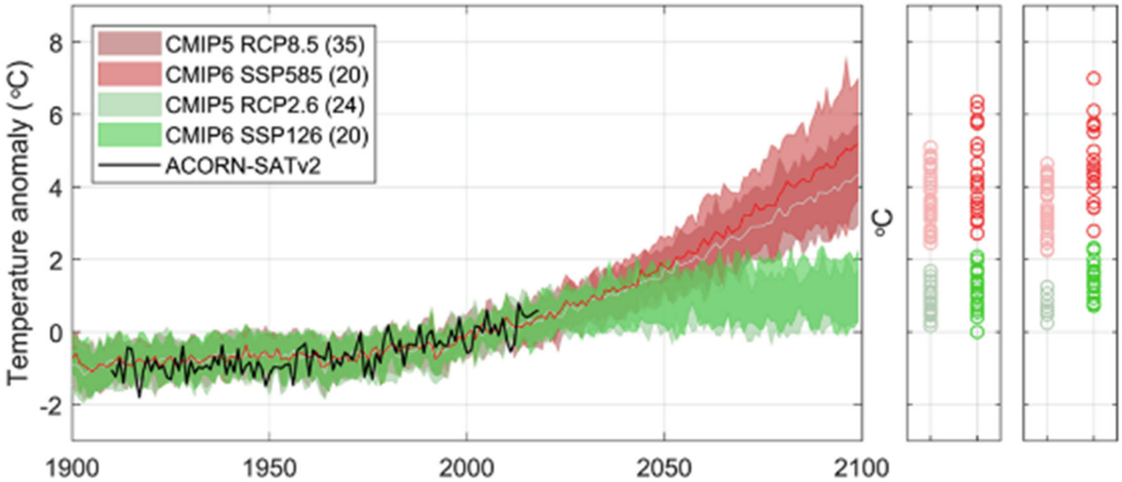


Figure 5.8 Mean annual surface air temperature anomalies from the 1995-2014 mean

for observations and two RCP and SSP scenarios. Australian mean temperature anomaly from the 1995-2014 mean showing 10-90 percentile of model range and the mean for RCP8.5 in CMIP5 (light red band, grey line), SSP5-85 in CMIP6 (red band, red line), RCP2.6 in CMIP5 (light green band), SSP1-26 in CMIP6 (green band)

In terms of time series and model spread, the temperature indices tend to start off cooler in CMIP6 than CMIP5, but see an acceleration between 2040 and 2070 such that by the end of the century, the projections are warmer in CMIP6 compared to CMIP5.

These Global CMIP6 models have not been downscaled yet to regional and local scale. Figure 5.9 shows a comparison between AR5 and AR6 projections across Australia depicting relatively higher mean temperature around Hobart City in AR6 projections compared to AR5 projections towards the end of the century. For temperature extremes, CMIP6 is decidedly warmer than CMIP5, being about 1°C warmer on the coldest night, 1.4°C warmer on the warmest day and more >30°C days contributing to more warm spells on average over land. The number of heatwaves days in predicted to increase the most in southern regions of Australia, by up to 100 days (WSD[1] in Figure 5.10).

[1] Warm spell duration index (WSDI) represents the days contributing to warm spells where the maximum temperature remains above the 90th percentile of climate data.

Warming in Australia between 1955-2014 compared to 2080-2099 is modelled to increase the most in western to central Australia in CMIP5 and from western to eastern Australia in CMIP6 (Figure 5.9).

Rainfall intensity is modelled to increase most in northern Australia (Rx1day in Figure 5.10) with an increase in heavy rain frequency concentrated in coastal areas and across Tasmania (R10mm in Figure 5.10). Across Australia, areas in central Queensland and Western Australia are modelled to have the highest increase in maximum length of dry spells (CDD in Figure 5.10).

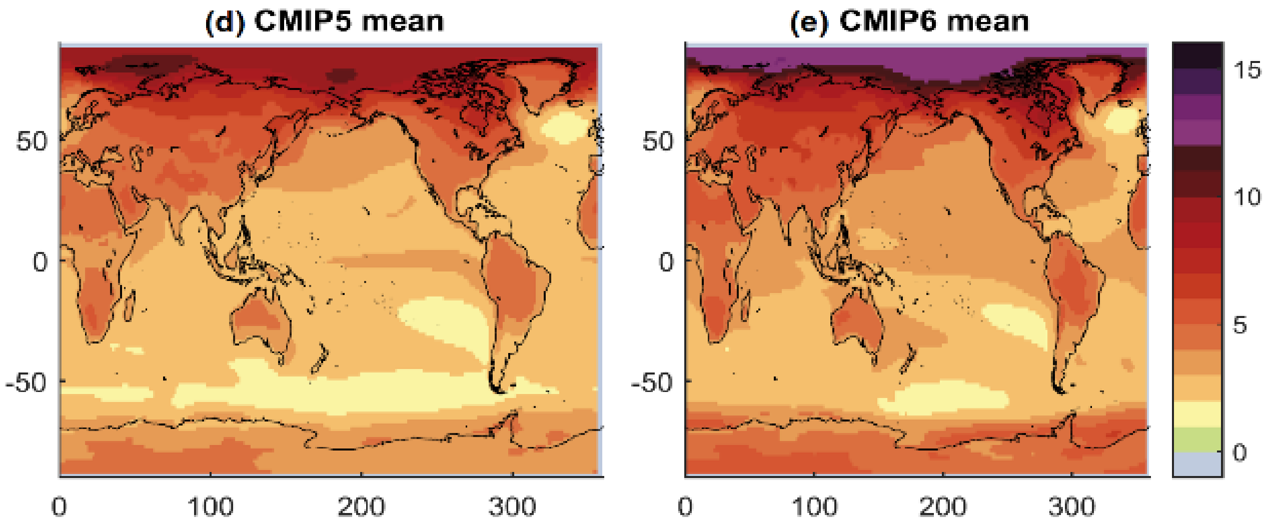


Figure 5.9 Multi-model mean warming between 1995–2014 and 2080–2099 in CMIP5 (left), and in CMIP6 (right). In CMIP6 slightly higher mean warming is projected in regions around Tasmania

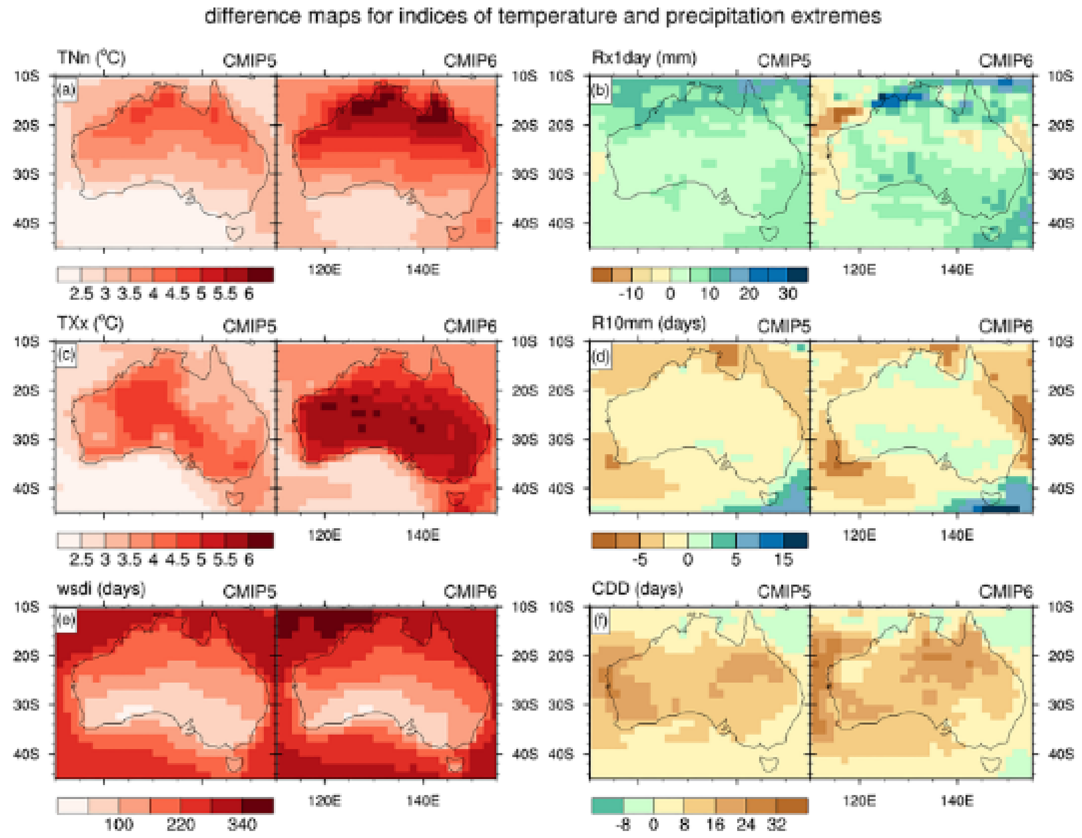


Figure 5.10 Projected change in six ETCCDI extremes indices between 1995-2014 and 2080-2099 under RCP8.5/SSP5-85. Each panel depicts CMIP5 results on the left and CMIP6 results on the right. The indices and the projected change over the land of Australia are (a) TNn which is the annual minimum (CMIP5 2.7°C, CMIP6 3°C); (b) Rx1day which is the maximum daily precipitation (CMIP5 10 mm, CMIP6 15 mm); (c) TXx which is the annual maximum of maximum temperatures (CMIP5 3.5°C, CMIP6 4°C); (d) R10mm which is the annual count of days when precipitation is more than 10mm (CMIP5 5 days, CMIP6 7 days); (e) wsdi which is the annual count of dry spell days (CMIP5 110 days, CMIP6 140 days); and (f) cdd which is the maximum number of consecutive dry days (CMIP 5 3.9 days, CMIP6 2.9 days)

6 Heat Assessment: Recommendations

The assessments presented in Section 4 and Section 5 investigate the current state of UHI across the Project Area through a range of analyses and assessed the spatial distribution of temperature profiles and projected heat influences impacted by climate change across varying timeframes.

There are a variety of measures that can help to reduce heat generation within urban areas. These include planning and design incorporating cool building materials, pavements and road surfaces, and increasing the amount of vegetation and water on the site. Examples include:

- Use of vegetation such as trees and other shade forming species;
  - Especially if strategically placed along prevailing wind corridors to enable passive cooling.
- Replacing heat absorbing infrastructure such as car parks with perforated surfaces such as vegetated areas;
- Using cool materials to increase reflectivity and emittance (cool roofs / cool and permeable paving);
- Use of water sensitive urban design; and
- Ensuring buildings are laid out in a way that allows maximum airflow

Urban heat is best managed using a suite of options and not being overly dependent on a single option alone.

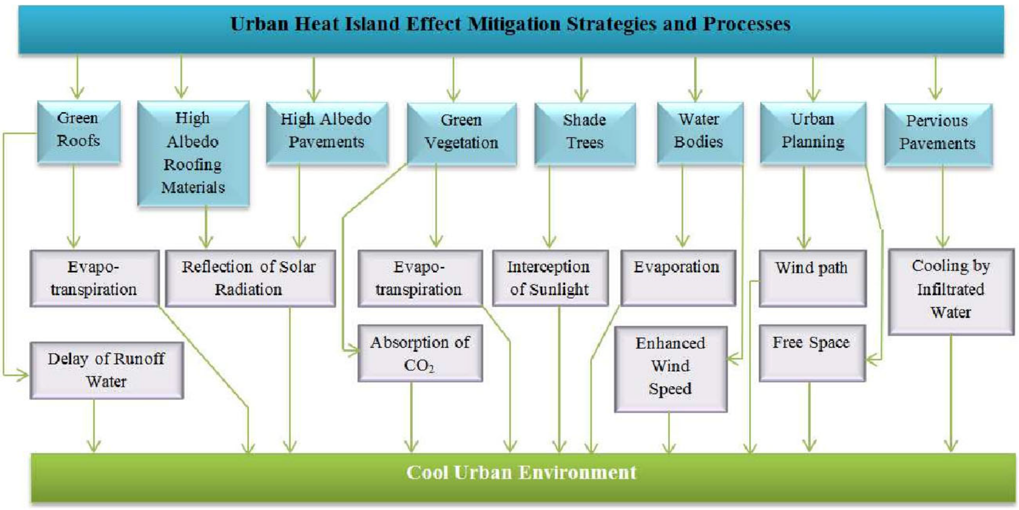


Figure 6.1 Urban Heat Management Options (Source: Nuruzzaman, 2015)

Increasing greening and planting trees are often seen as a means to improve the urban climate. Research has however shown that these measures may not be the most optimal or sustainable strategies in some circumstances. Additionally, the effects of these measures may vary between localities and different urban structures. Due to climate change and associated drought impacts, water availability for sustaining the maintenance of trees and grasses is becoming a challenge. This may result in a die-off of vegetation and affect tree health and canopy cover. Accordingly, using a diverse mix of UHI mitigation measures may be more sustainable and cost effective over the medium to long-term.

Options include increasing the albedo of roof, pavements and parking; plantation of appropriate climate resilient species in strategic locations; and installing water sprinklers that are preferably using recycled water. Water sensitive urban design can help ensure a sustainable water supply is available for vegetation.

6.2 Planting Trees

Planting new trees in strategically selected areas can be a low-cost solution. The planting of trees reduces heats in two ways. Trees shade buildings, pavements, and other surfaces. Shading works by preventing solar radiation from reaching walls and pavements, decreasing the heat conducted into buildings and into the surrounding air. Trees also reduce air temperatures indirectly through evapotranspiration. In this process, trees absorb water through their roots and emit it back into the air. Ambient heat converts the water into vapour, thus dissipating the energy. Overall, the cooling benefits of trees can be large. Additional added benefits include visual aesthetics and provision of habitat for fauna. The heat management and mitigation benefits can be verified through urban heat simulation and scenario testing.

Despite the limitation of trees, there are several challenges. Planting and pruning of trees are usually the largest expenses, but litter management, watering, stump removal, inspection and administration also require expenditures. Trees may also present safety hazards with broken branches causing damage to property or cause injury in heavy storms. With expected variations in water availability due to drought conditions and increased storms, tree management can be challenging.

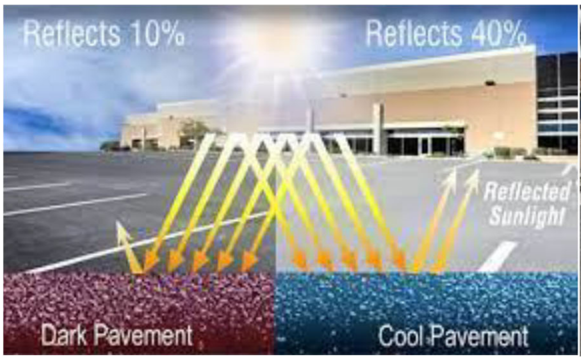
6.3 Use of Cool Pavements

Using cool materials (tiles, paints, membranes, etc) in the pavement of the parking or pedestrian areas across the Project Site is another heat management option. Applying this option in strategically selected areas (e.g. the hot areas identified in Figure 4.2 and Figure 4.3) along with the strategic placement of planted trees can help reduce air temperature. The degree of reduction in air temperature can be verified through urban heat modelling and simulation testing. Cool materials usually present a light colour, but darker coloured materials can be used if they present high reflectivity in the infrared spectrum.

The benefit of a cool pavement is that it absorbs less solar radiation of traditional dark asphalt or concrete pavements, meaning they heat less and release less heat. From measurements in scientific literature, a traditional dark asphalt concrete pavement with an albedo of 0.15 when aged, may exceed 60°C (surface temperature) in peak summer conditions. In the same conditions, a cool pavement with albedo of 0.4 can be cooler by even 8°C (surface temperature). Cool pavements can help improve the thermal comfort in nearby buildings as well as reduce their energy needs through a reduction in air conditioning requirements in summer. While cool pavements may reduce the surface temperature of the pavement itself, the air temperature above is not directly related and therefore may not decrease (Santamouris, 2016).

Permeable pavements are also another form of cool pavements where air, water and water vapour is allowed into the voids of the pavement. When these permeable surfaces get wet, they lower temperatures through evaporative cooling. These permeable surfaces can also be vegetated using species such as grasses.

Despite the benefits of cool pavements, they can present some challenges. First, cool pavements are still be tested in a variety of locations, as their performance heavily depends on local conditions such as traffic, shadiness, and the specific use of the paved areas. Second, pavements do not directly cool buildings, but instead reduce building temperatures indirectly by cooling the surrounding area. Because cool pavements do not affect the habitability or energy use of particular structures, their benefits are more difficult to quantify. Third, cool pavements can cause glare issues, potentially reflecting light back into the eyes of pedestrians or users of the pavement. Additionally, the reflectivity of cool pavements can equate as much as 10% increase in direct sunlight, which can be uncomfortable for pedestrians on very sunny days. It is noted that this isn't as much as an issue for grass paving.



6.4 Use of Cool Roofs

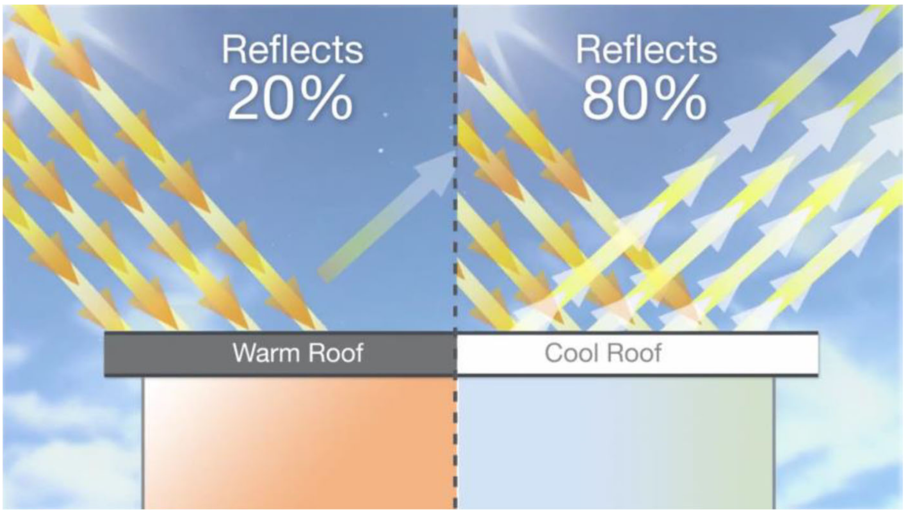
A cool roof or reflective roof is a roof which reflects most of the sunlight. This allows the roof to not overheat and stays cool, a preferrable option for cooling the Macquarie Stadium if it is to be roofed. These roofs can be a white or a cool coloured surface and look like a traditional roof, except they use paint that absorbs less solar radiation, yielding a lower surface temperature.

Painting the roof of existing or new buildings with high albedo materials (0.75) can be one option for heat reduction across the Project Site. Using this approach in combination with the other recommended mitigation measures may result in a sizeable reduction in air temperature which can be verified through urban heat modelling. However, this option has some cost implications for existing structures and will require consultation with the current asset owners.

The use of cool roofs can save energy in air-conditioned buildings and can improve indoor thermal comfort in buildings with air-conditioning. In poorly insulated buildings, cool roofs can help improve energy efficiency by lowering the ceiling and indoor air temperatures. They can also reduce the heat that is released into the urban atmosphere and increase the service life of the roof. Reducing the temperature of the roof can cause fewer thermal shocks compared to a traditional. This has both health and financial benefits for users of buildings which cool roofs have been applied.

Reflected materials applied to the roof of buildings are white and may be single ply or liquids. Typical single ply products are EPDM (Ethylene Propylene Diene Terpolymer Membrane), CPE (Chlorinated Polyethylene), PVC (Polyvinyl Chloride), TOP (Thermoplastic Polyolefin), and CPSE (Chlorosulfonated Polyethylene). Liquid products are usually white paints, elastomeric, acrylic or polyurethane coatings.

The challenges associated with cool roofs are that they require some maintenance to sustain their effectiveness. Cool roofs generally have initial reflectance levels of 55 to 90%, compared to traditional roofs, which have 5 to 25%. Weathering and dirt accumulation can lower the solar reflectance of cool roofs over time. Studies have found an average decline of 15% in solar reflectance after the first year, with less significant declines of the following five years (Bretz & Akbari, 1997). However, washing can restore the cool roof to near its original solar reflectance (Haverstic et al., 2017; Saber et al., 2021). Whether the energy savings are larger than the cost of washing depends on the local climate and building insulation levels. Cool roofs have typically been found to be more reflective than traditional roofs even after weathering; suggesting that they are worth the slight cost premium.



6.5 Manage Urban Heat Using Evidence-Based Microclimate Simulations

The effectiveness of the prementioned UHI recommendations discussed in reducing heat for the Project Site can be determined through microclimate simulations and scenario testing. A microclimate simulation is an advanced, fine scale modelling technique that simulates the microclimate of a site (like a digital twin) and can be used to evaluate the effectiveness of the prementioned UHI management options in reducing urban heat. This includes simulation individual mitigation measures or a combination of mitigation measures to determine their effectiveness, as well as suitability for the Project Site.

A microclimate of the Project Site can be controlled by a multitude of different man-made and natural elements forming the urban landscape and site characteristics (existing urban fabric, materials of buildings and surfaces, arrangement of urban layout, extent of vegetation, local climate conditions etc). They all have their individual characters and contribute in their own way to the formation of wind flows, radiation patterns or air temperature. Simulation of these microclimate features through computational fluid dynamics software (e.g. Envi-Met) enables users to understand the impact of different site features on its microclimate. Microclimate simulation models analyse microscale thermal connections in urban environments. The model utilises the thermodynamic procedures taking place at the ground surface, walls, roofs and plants. In addition to the calculation of fluid dynamics features like turbulence and air flow, the software considers all kinds of solar radiation: direct, reflected and diffused, and estimates different microclimate parameters. This allows planners, architects and engineers to make evidence-based design choices for urban design by testing future design scenarios.

Further, microclimate simulations can be calibrated by installing sensors and weather stations on site to collect Project Site specific weather data including hourly data for temperature (air and surface), humidity, wind velocity and direction. This enables a highly localised microclimate simulation to sufficiently establish the current climate of the Project Site before testing the influence of heat mitigation controls and their effectiveness in heat reduction from potential future design conditions on the Project Site.

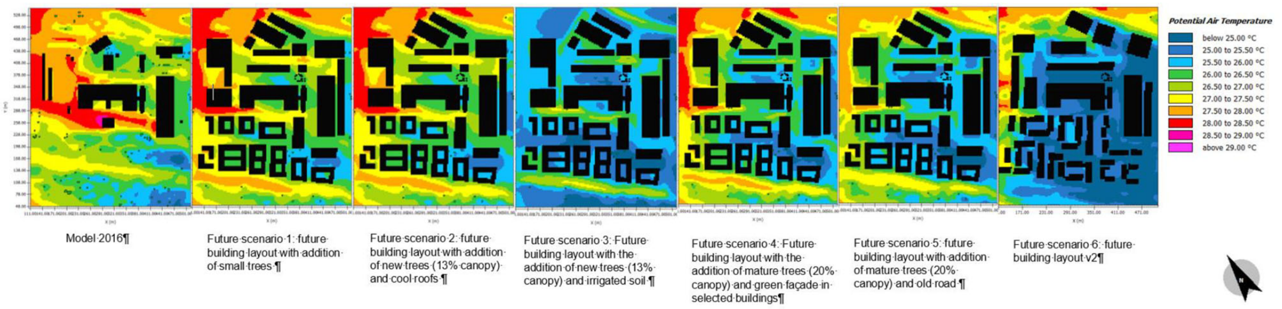


Figure 6.2 Example comparison of air temperature between current site conditions and future design scenarios

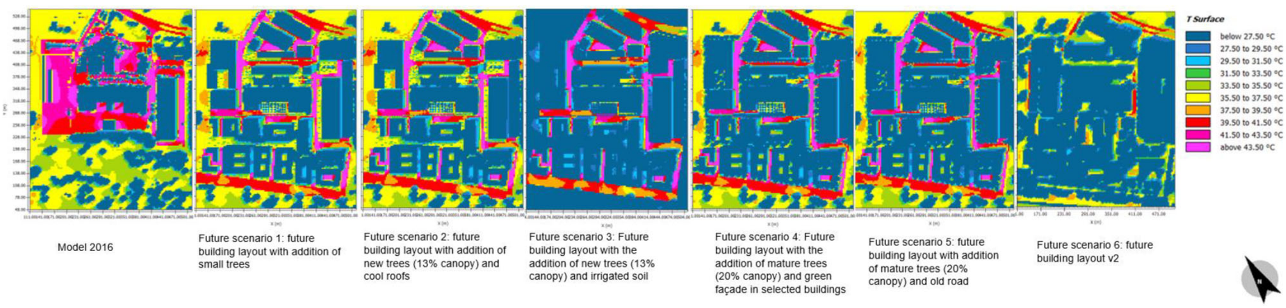


Figure 6.3 Example comparison of surface temperature between current site conditions and future design scenarios

7 Conclusion

The UHI profile, projected climate change influences and preliminary mitigation measures for consideration for the proposed development of the Project Area have been presented. Based on this desktop assessment and detailed analysis, a range of recommendations have been provided for consideration during the design of the Macquarie Point Site and Multipurpose Stadium.

It is significant to note that heatwaves remain a natural process which is endemic to the Australian landscape, and it remains subject to a range of contributing factors which are variable on a daily, monthly, and seasonal basis. Climate change is expected to exacerbate the frequency, duration and occurrence of heatwaves contributing to the UHI effect, as well as influencing increases to sea level and rainfall. On this basis, it is important that current and future heatwave stress, sea level rise and rainfall is considered into the design of the Macquarie Point Site to alleviate future urban heat island effect.

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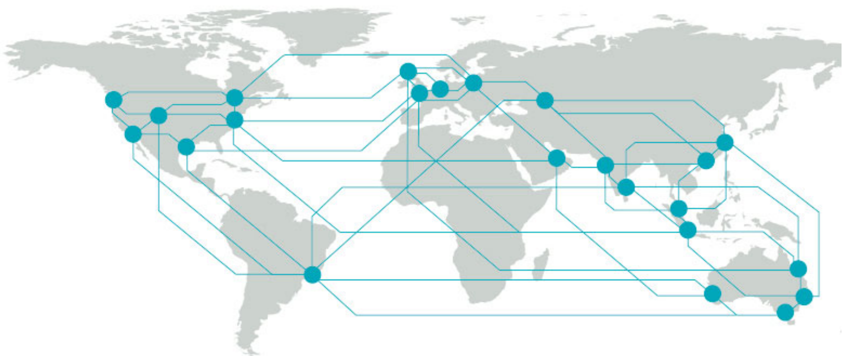

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