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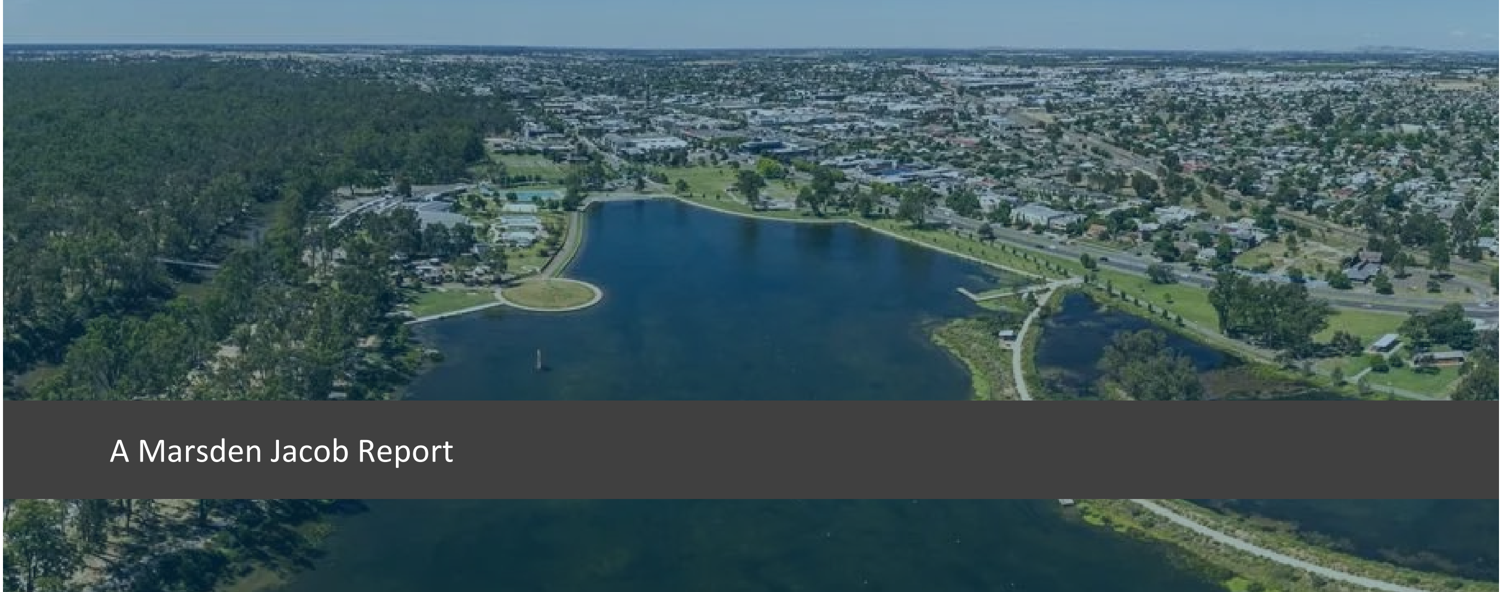
MARSDEN JACOB ASSOCIATES

Mitigating the Impacts of Extreme Heat in the City of Greater Shepparton

A Resilient Public Estate Asset Vulnerability Assessment Case Study: Final report

18 June 2024



A Marsden Jacob Report

Prepared for Goulburn Murray Climate Alliance and City of Greater Shepparton
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Executive Summary

Introduction

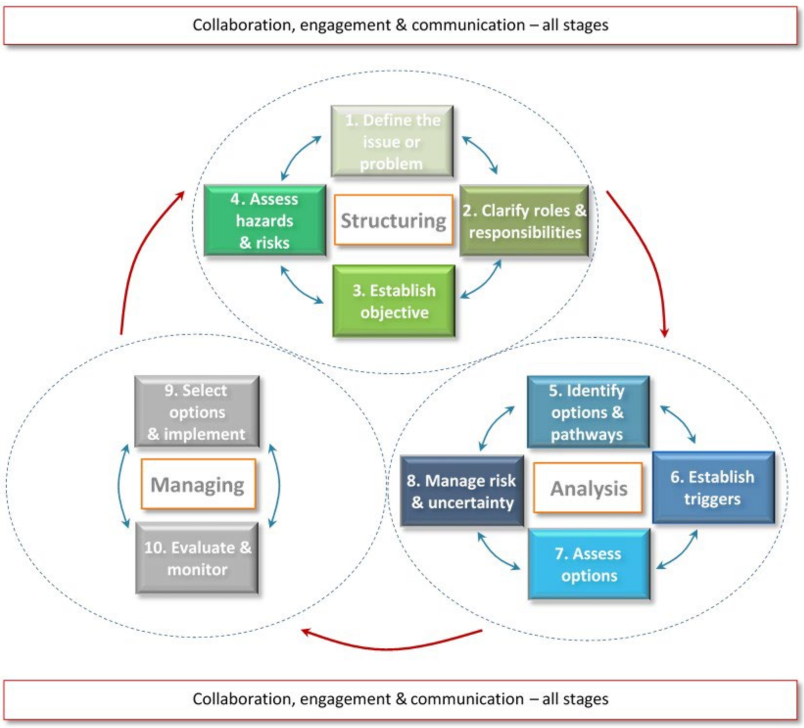
Goulburn Murray Climate Alliance (GMCA) member councils are seeking to better understand how their buildings, roads, drains, other built assets, natural assets and associated services will be impacted by climate change. The Climate Change Asset Vulnerability Assessment project seeks to provide councils with this information. Guidelines on climate change adaptation decision making have been developed as part of the project. The purpose of the case studies is to provide practical examples of the adaptation decision-making process as set out in the guidelines.

This case study assesses the benefits and costs of increasing tree canopy cover in Greater Shepparton focusing on the benefits that increasing tree cover will have on reducing the Urban Heat Island (UHI) effect and mitigating the adverse health impacts of extreme heat across the urban and peri-urban areas of Greater Shepparton. The benefits of increasing tree canopy cover in the rural town of Dookie are also discussed qualitatively.

Climate change adaptation decision making

A sound decision-making process provides the foundation for effective climate change adaptation. Figure ES 1 identifies the key stages and steps comprising 'good practice' adaptation decision making.

Figure ES 1. Stages in the decision-making process



Working with the Greater Shepparton City Council we have undertaken preliminary analysis relating to Steps 1 through 8 in that process, however the primary focus of our analysis has been on options assessment (Step 7).

Problem definition

The City of Greater Shepparton has a climate characterised by hot dry summers and cool winters. It's climate more closely approximates that of Mildura and inland NSW than it does southern Victoria. Moreover, climate change projections indicate that the City of Greater Shepparton will continue to become hotter, with associated increases in the frequency or severity of heatwaves and extreme heat days.

According to the State Crisis and Resilience Council heatwaves are the 'silent killer' of extreme weather events and are the leading cause of weather-related deaths in Australia. Recognising the importance of local planning for heatwaves, the Greater Shepparton Municipal Emergency Management Planning Committee (MEMPC) is currently developing a new Extreme Heatwave Complementary-Plan of the Municipal Emergency Management Plan (MEMP).

Numerous Australian and international studies have examined the relationship between extreme heat, heatwaves and adverse health outcomes including morbidity requiring hospitalisation or other emergency medical care, and premature mortality especially in older people. Drawing on the method applied in McMichael et al. 2003 and Woodruff et al. 2007, we have made a preliminary estimate of heat related deaths in Greater Shepparton. We estimate that in 2021 11 people in Greater Shepparton could have died from heat-attributable factors or about 2% of all deaths in that year. Based on population and climate change projections for Greater Shepparton heat-related deaths could increase to between 25 and 28 by 2050.

Recent Australian studies have examined the relationship between tree canopy or vegetation cover and surface temperatures in urban areas (Cheesman and Rogers 2023, Duncan et al. 2018, Sun et al. 2018). These studies all demonstrate the potential for increased tree canopy cover to significantly ameliorate urban heat, especially during heatwaves, with resulting health benefits including reduced heat-related deaths and reduced hospitalisation and other emergency medical care.

Adaptation options assessed

The Greater Shepparton City Council has recognised the benefits of enhancing tree canopy cover and in 2017 initiated an *Urban Forest Strategy for Greater Shepparton*. The overarching strategy target is to achieve 40% tree canopy cover across the urban and peri-urban areas of Greater Shepparton by 2037. Extensive planting of trees in urban areas to increase tree canopy cover is the preferred and arguably only feasible option available to regulate ambient temperatures in Greater Shepparton. Two variants of this option have been assessed for the case study. These are defined as:

Option 1 - continue to implement the Urban Forest Strategy 2017-2037, with the Strategy target of achieving 40% canopy cover in Greater Shepparton by 2037.

Option 2 - continue to implement the Urban Forest Strategy 2017-2037, but with a reduced target of achieving 30% canopy cover in Greater Shepparton by 2037.

These two options were assessed through a cost-benefit analysis (CBA), with costs and benefits of the two options being assessed relative to a Base case of not implementing the Strategy and tree canopy cover across Greater Shepparton therefore remaining at its current level of 18.3 %.

Analysis of options

Results of the cost benefit analysis (CBA) are presented in Table ES.1. The results are based on the following generic assumptions:

- a 4% real discount rate;
- a 25-year analysis period;
- climate projections over the analysis period are based on the moderate climate change scenario (RCP 4.5); and
- all cost and benefit values are in 2024 dollars.

Table ES.1. Cost benefit analysis results of increasing tree canopy cover to 40% (Option 1) and 30% (Option 2) under the moderate climate change scenario

Costs and benefits	Option 1 (Increasing tree canopy cover to 40%)	Option 2 (Increasing tree canopy cover to 30%)
Costs		
Capital costs	$3,639,800	$1,955,000
Operating costs	$32,160,900	$19,251,300
Total Costs (present Value)	***$35,800,700***	***$21,206,400***
Benefits		
Avoided health impacts of air pollution	$2,613,200	$1,407,800
Value of lives saved	$58,461,300	$36,043,800
Avoided healthcare costs	$4,720,500	$2,776,800
Increased mental wellbeing	$15,087,200	$15,087,200
Total Benefits/Avoided Costs (Present Value)	***$80,882,300***	***$55,315,700***
Net Present Value (NPV)	**$45,081,600**	**$34,109,300**
Benefit Cost Ratio (BCR)	**2.26**	**2.61**

Table ES 1 shows that Option 1 – Increasing tree canopy cover to 40% by 2037 in Greater Shepparton - will result in an NPV of $45.1 million and BCR of 2.26. This means that every $1 spent on the Strategy will result in a benefit of $2.26. The main driver of this expected outcome is the benefit arising from avoided premature mortality amongst people aged over 65 years. Increased mental health wellbeing, avoided healthcare costs (hospitalisations and emergency department visits) and avoided health impacts of air pollution across vulnerable sections of the community are also expected to be significant benefits.

Table ES 1 also shows results for Option 2. Increasing tree canopy to the lower target of 30% will result in an NPV of $34.1 million and a BCR of 2.61. The higher NPV but lower BCR of Option 1, compared to Option 2, reflects both greater benefits and greater costs of Option 1, but with the additional benefits of increasing tree canopy cover from 30% to 40% being proportionately less than the additional costs of the increase.

The results for both Option 1 and Option 2 could be conservative because some non-health benefits of increased tree canopy cover have not been valued in the analysis. These include improved productivity, reduced runoff following extreme rainfall events, and the ecological, amenity and recreational benefits of enhanced tree cover. On the other hand, the results do not capture the possibility that other adaptation measures, such as those implemented through Greater Shepparton's Extreme Heat Complementary-Plan and Climate Emergency Action Plan, could in part mitigate the health effects of extreme heat in Greater Shepparton in the future.

Sensitivity testing has been undertaken to clarify which assumptions can materially change the results. Under all changes increasing tree canopy cover to either 40% (Option 1) or 30% (Option 2) in Greater Shepparton achieves a positive NPV and BCR greater than 1.

Conclusions and next steps

Notwithstanding uncertainties and gaps in the analysis, it is highly likely that continued implementation of the Urban Tree Strategy with a target tree canopy cover of 40% (Option 1) will result in substantial net benefits to the community of Greater Shepparton. Reducing the Strategy target to 30% (Option 2) will result in lower benefits than Option 1 but will still lead to a substantial net benefit.

A number of steps can be undertaken to ensure that the targeted tree canopy cover of 40% is achieved and in doing so meets the objective of reducing the UHI and associated extreme heat days. These include:

- ensuring that the number, mix and location of new tree plantings is optimised;
- replacing hard surfaces with natural surfaces; and
- undertaking a comprehensive community education and engagement on the urban heat and other benefits of increasing tree canopy cover.

1. Introduction

Goulburn Murray Climate Alliance (GMCA) member councils are seeking to better understand how their buildings, roads, drains, other built assets, natural assets and associated services will be impacted by climate change. The *Climate Change Asset Vulnerability Assessment* project seeks to provide councils with this information.

Guidelines on climate change adaptation decision making have been developed as part of the project. The purpose of the case studies is to provide practical examples of the adaptation decision-making process set out in the guidelines. Each case study goes through a systematic process of identifying and assessing adaptation options[1] for a priority asset or service that was identified through the vulnerability assessment. Two studies were selected for the case study phase following a review of case study proposals that were nominated by GMCA councils.

This case study assesses the benefits and costs of increasing tree canopy cover in Greater Shepparton focusing on the relationship between tree cover, urban heat and health outcomes. Due to a changing climate, the frequency and severity of extreme heat days are projected to increase, with an associated increase in adverse health outcomes. The health benefits of tree cover have been measured by evaluating the impact of increased tree canopy cover on reducing the Urban Heat Island (UHI) effect in the urban and peri-urban areas of Greater Shepparton, especially during periods of extreme heat and heatwaves, thereby mitigating the adverse health impacts of extreme heat.

Other benefits of enhanced tree cover are also considered.

The benefits of increasing tree canopy cover in the rural town of Dookie are also discussed qualitatively.

We emphasise that the case study presents a preliminary assessment and, as such, provides only initial guidance on the heat health benefits of Greater Shepparton City Council's Urban Forest Strategy and considerations about any changes to that Strategy or to the Extreme Heat Complementary-Plan of the Municipal Emergency Management Plan (MEMP) that might be considered as a consequence of this analysis.

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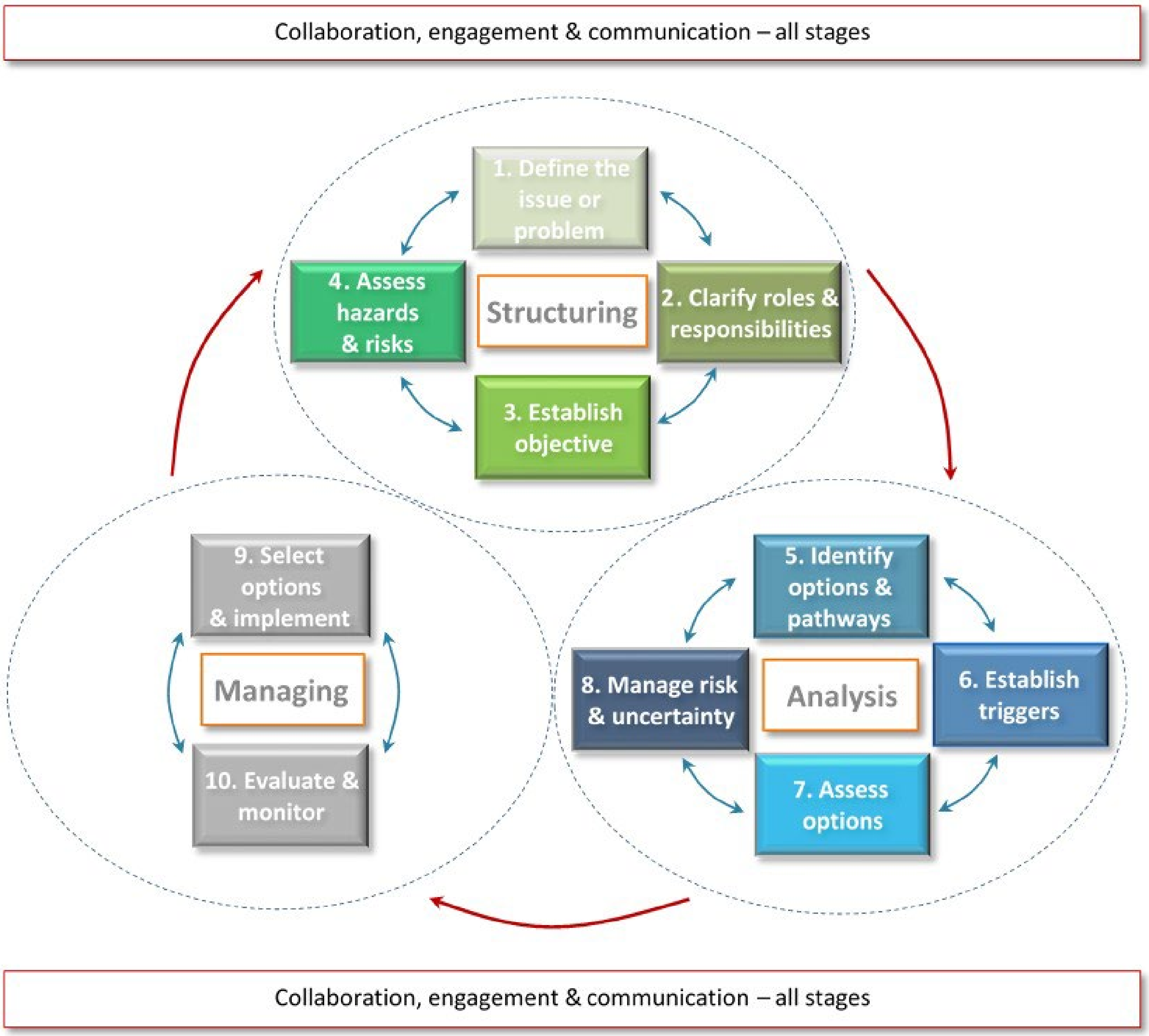
[1] Climate change adaptation can be defined as actions taken in response to actual or anticipated climate change impacts that lead to a reduction in risks or a realisation of benefits.

2. Climate change adaptation decision-making process

A sound decision-making process provides the foundation for effective climate change adaptation. Figure 3 identifies the key stages and steps comprising 'good practice' adaptation decision making. Working with the Greater Shepparton City Council we have undertaken some preliminary analysis relating to Steps 1 through 8 in the process, however the primary focus of our analysis has been on assessing adaptation options (Step 7) and consideration of uncertainties in the analysis (Step 8). Steps 1 to 6 are discussed briefly in this section, with more detailed discussion of Steps 7 and 8 provided in the following sections.

Figure 1: Stages in the decision-making process



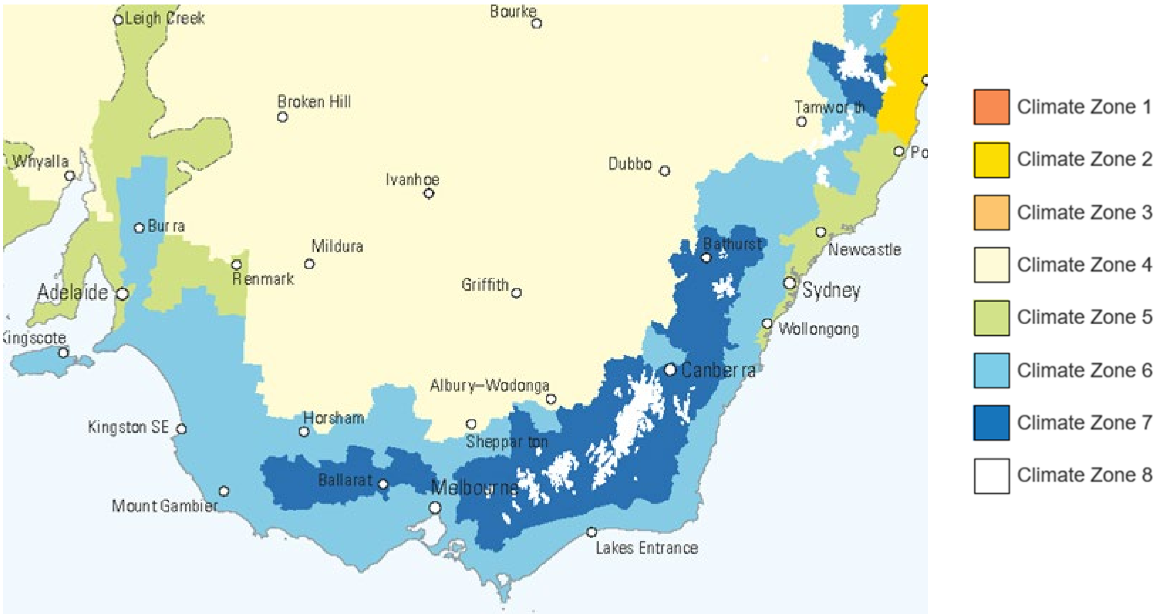
Source: Marsden Jacob Associates

2.1 Problem definition: mitigating the health impacts of extreme heat in a changing climate

2.1.1 Extreme heat and climate change in Greater Shepparton

The City of Greater Shepparton is located in central north Victoria, on the floodplains of the Lower Goulburn and Broken Rivers. It has a climate characterised by hot dry summers and cool winters (see Figure 2). As such, its climate more closely approximates that of Mildura, inland NSW and (in summer) Adelaide or Perth than it does Melbourne and other parts of southern Victoria. The mean maximum temperature in Shepparton in January is 32°C, with the average number of days > 35°C each year being 18 and the average number of days > 40°C being 2.2[2]. Moreover, climate change projections indicate that, consistent with other parts of Victoria and Australia, the City of Greater Shepparton will continue to become hotter, with associated increases in the frequency or severity of heatwaves and extreme heat days. Current projections are that the number of days in Shepparton each year > 35°C will increase to between 27 and 32 days by 2050[3].

Figure 2: National Construction Code climate zones, SE Australia



Source: Australian Building Code Board

a. *Climate Zone 4 (e.g. Shepparton) – Hot dry summer, cool winter*

b. *Climate Zone 5 (e.g. Adelaide) – Warm temperate*

c. *Climate Zone 6 (Melbourne) – Mild temperate*

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[2] Sourced from BoM data for Shepparton Airport 1996-2023 - http://www.bom.gov.au/climate/data/. This compares with an average of 17 days each year > 35°C in Adelaide (with a mean January max of 30°C), 28 days in Perth (with a mean January max of 32°C), but only 10 days in Melbourne (with a mean January max of 26°C).

[3] Sourced from Victoria's Future Climate Tool - https://vicfutureclimatetool.indraweb.io/project.

2.1.2 Health impacts of extreme heat

According to the State Crisis and Resilience Council heatwaves are the ‘silent killer’ of extreme weather events and are the leading cause of weather-related deaths in Australia (SCRC 2020). Victoria’s Department of Health (DoH) defines extreme heat based on its heat health temperature thresholds. In the Greater Shepparton region (Northern Country) that threshold is 32ºC (Figure 3).

Figure 3: Heat health thresholds in Victorian regions

Source: Victorian Department of Health

The importance of local planning for heatwaves and days of extreme heat are recognised in the *Emergency Management Act 1986 & 2013.* Consistent with the Act, the Greater Shepparton Municipal Emergency Management Planning Committee (MEMPC), chaired and supported by the Greater Shepparton City Council (GSCC), is currently developing a new Extreme Heat Complementary-Plan of the Municipal Emergency Management Plan (MEMP). This Complementary-Plan will supersede Greater Shepparton’s *Heatwave Plan 2018-2021*. Through the Complementary-Plan, member organisations of the MEMPC will provide the community with information and engage with local stakeholders to develop processes that protect residents and visitors from extreme heat.

As detailed in the Heatwave Plan 2018-2021, there are a number of population groups who are more vulnerable to the effects of heatwaves and extreme heat events. These groups include:

- Older people, living alone without support, especially people aged over 75
- Socially or physically isolated people
- People relying on external help including older people, people with existing disability, physical or mental

illness and people confined to bed

- Financially disadvantaged
- Families with young children, pregnant and nursing mothers, and children under 5 years of age
- People with a pre-existing medical condition or chronic disease.

They may also include people in the following circumstances:

- People without air-conditioning or who refuse to use it
- Homeless people
- Low income earners
- People who are outdoors for any reason, especially doing strenuous activity, such as physical work or playing sports
- Culturally and linguistically diverse backgrounds, non-English speaking.

Numerous Australian and international studies have examined the relationship between extreme heat, heatwaves and adverse health outcomes including morbidity requiring hospitalisation or other emergency medical care, and premature mortality especially in older people (see for example Li et al. 2015). Some of the studies have examined the relationship between extreme heat and premature deaths in people aged 65 years and older (e.g. McMichael et al. 2003, Woodruff et al. 2007). These studies have estimated that in the analysis period about 1100 people died each year due to heat in Australian capital cities. A much higher death rate was modelled in Adelaide and Perth (both in the hot/dry zone) than in other cities, due to the higher frequency with which maximum temperatures above 35 and 40 degrees are recorded in those cities. The studies further estimated that by 2100 heat-related deaths could increase by 4 to 8 times due to a combination of climate change, population growth and an increase in the proportion of the population over the age of 65. The authors emphasised that these estimates do not account for acclimatisation and the potential for adaptive strategies, such as increased use of air-conditioning, to reduce the risks of exposure to heatwaves.

Extreme heat impacts in Greater Shepparton

Drawing on the method applied in McMichael et al. 2003 and Woodruff et al. 2007, we have made a preliminary estimate of heat related deaths in Greater Shepparton. We estimate that in 2021 (the most recent year for available census and mortality data) 11 people in Greater Shepparton could have died from heat-attributable factors. This represents just under 2% of all deaths in that year or a death rate of 83/100,000 over the age of 65. In proportional terms, our estimate is somewhat lower than the estimates for Adelaide in McMichael et al. 2003 and Woodruff et al. 2007 (2.9% of deaths heat-related in the period examined, and a death rate of 122/100,000) and significantly less than their estimates for Perth (4.8%, 195/100,000). Based on population and climate change projections for Greater Shepparton we further estimate that annual heat-related deaths could increase to between 25 (moderate climate change scenario) and 28 (high climate change scenario) by 2050.

An important difference in the approach we have taken compared to the source studies is that in the source studies the threshold temperature for temperature-attributable mortality is 28°C, with the same threshold being applied to all Australian cities. For our analysis, we have used 30°C as the threshold to reflect extreme heat temperature thresholds applied by DoH. This means that our estimates are more conservative than those of the sources studies but in applying a higher threshold temperature our estimates arguably better reflect acclimatisation and the effects of existing adaptive strategies.

2.1.3 Mitigating extreme heat through increased tree canopy cover

Recent Australian studies have examined the relationship between tree canopy or vegetation cover and surface temperatures in urban areas (Cheesman and Rogers 2023, Duncan et al. 2018, Sun et al. 2018). These studies all demonstrate the potential for increased tree canopy cover to significantly ameliorate urban heat, especially during heatwaves, with resulting health benefits including reduced heat-related deaths and reduced hospitalisation and other emergency medical care.

Increasing tree canopy cover can lead to a range of other benefits too, including reduced water runoff during high intensity rainfall events, reduced urban air pollution, carbon sequestration and amenity and recreation benefits.

Greater Shepparton’s Urban Forest Strategy

In 2017, the urban and peri-urban areas of Greater Shepparton had an estimated tree canopy cover of 15.7% (Active Green Services 2023). This is similar to the average tree canopy cover across Greater Melbourne (13.6%), significantly greater than the western suburbs of Melbourne (5%) but substantially lower than some peri-urban areas to the east and north-east of Melbourne (e.g. Nilumbik and Yarra Ranges 35-40%) (Hurley et al. 2019).

The Greater Shepparton City Council has recognised the benefits of enhancing tree canopy cover and in 2017 initiated an *Urban Forest Strategy for Greater Shepparton* (Urban Forest Consulting 2017). The overarching strategy target is to achieve 40% tree canopy cover across the urban and peri-urban areas of Greater Shepparton by 2037. Approximately six years into the strategy and with tree canopy cover estimated currently to be about 18.3% (Active Green Services 2023) it is worth assessing the costs and benefits of the strategy and especially the potential health benefits of achieving a 40% tree canopy cover.

Council also implements the ‘One Tree Per Child’ revegetation program, that plants on average 25,000 native grasses, shrubs or trees in the municipality each year. This OTPC program targets rural roadsides, schools and council-managed open spaces, rather than the street-tree and urbanised settings where the Urban Forest Strategy is focused.

2.2 Roles & responsibilities

As previously noted, the Greater Shepparton Municipal Emergency Management Planning Committee (MEMPC), chaired and supported by the Greater Shepparton City Council (Community Directorate), is responsible for developing and updating the Extreme Heat Complementary-Plan of the Municipal Emergency Management Plan (MEMP). Membership of the Committee includes representatives of the emergency service agencies such as the CFA, FRV, Ambulance Victoria, Victoria Police and Victoria State Emergency Service, Department of Families, Fairness and Housing, Department of Health, as well as other state departments, local community groups and organisations with a role in emergency management such as the Red Cross.

The Urban Forest Strategy is the responsibility of Greater Shepparton City Council through its Parks, Sport and Recreation Department.

Members of the local community have important roles to play in ensuring effective implementation of both the Extreme Heat Complementary-Plan and the Urban Forest Strategy.

When implementing both the Urban Forest Strategy and the Extreme Heat Complementary-Plan it will be important to ensure that the potential heatwave mitigation benefits of increasing tree canopy cover are apparent to the MEMPC, the Community Directorate of Council and the Parks, Sport and Recreation Department of Council and to the wider community.

2.3 Objective(s)

A clearly defined objective or objectives are important to assisting Council with the process of identifying and assessing adaptation options and for guiding decision-making on adaptation. Where there are multiple objectives, it is important to determine which objective will take priority and in what circumstances or locations, especially if there is a potential for some of the objectives to reflect competing priorities.

The Urban Forest Strategy has multiple objectives which, as detailed in the strategy, include:

1. Improve community health and wellbeing: by planting and maintaining shady welcoming streets encouraging people to walk and cycle.
2. Assist the region to adapt to climate change: by providing shade, reducing stormwater flows and planting tree species that are resilient for the future.
3. Create habitat corridors between townships and surrounding natural areas: by planting street tree species that support habitat movement through urban streets, thereby improving connectivity for biodiversity.
4. Improve the attractiveness and economic prosperity of the CBD and commercial areas.
5. Improve Greater Shepparton's overall liveability and streetscape amenity.
6. Encourage the community to be involved in planting and caring for the urban forest.

Although not explicitly stated in these objectives, the Urban Heat Island (UHI) and associated health benefits of increasing tree canopy cover are at least implied in Objectives 1 and 2. If however, Council deems the UHI benefits of urban forestry to be important, it may be useful to amend the objectives to make this objective more explicit. Moreover, it is important that when implementing the strategy any potential inconsistencies between UHI and other objectives are considered and appropriate responses developed. For example, the species and siting of trees most suited to enhancing amenity or providing habitat corridors, pollination or other biodiversity benefits may not always be the species and siting of trees best suited to providing shade and mitigating heat. Therefore, careful consideration is needed to determine which objective has priority in each location and ensure appropriate species selection given that priority.

2.4 Hazards and risks

2.4.1 Health risks posed by extreme heat

As described in section 2.1.2, an initial quantitative analysis of the health risks posed by heatwaves to the community of Greater Shepparton has been undertaken for this study, drawing on earlier studies. The analysis also builds on the *Climate Change Asset Vulnerability Assessment*, which provides information on temperatures and extreme heat for the region under climate change scenarios. Further detailed analysis of the relationship between extreme heat in Greater Shepparton and health outcomes is probably not warranted at this stage, but it may be useful for the MEMPC to maintain a watching brief on climate change science and developments in the understanding of how changes in the frequency or severity of heatwaves in the future could impact on health outcomes.

2.4.2 Risks to achieving objectives of the Urban Forest Strategy

There are significant risks to achieving objectives of the Urban Forest Strategy and associated UHI and other objectives of the Strategy. These risks fall into two interrelated categories:

First, are the difficulties of planting and establishing trees in urban environments due to:

- Competition for above and below ground space (because space can be limited).
- Soil in urban areas often being compacted, excavated and horizontally bored. Consequently, tree survival rates can be reduced with hard surfaces underneath radiating heat to the underside of trees (which does not typically occur in more natural environments).
- Trees need to be pruned for electrical line clearance.

Second, is the social environment in which the Urban Forest Strategy is being operated:

- The urban cooling and other benefits of trees are not necessarily understood or valued by all community members. Consequently, there can be resistance to street trees in estates from some residents (due to wanting to park vehicles on nature strips; damage to infrastructure/drains from roots; leaves and dropping limbs from trees; and even site visibility concerns). Some residents have been known to deliberately damage and kill the planted trees.
- There can be tensions between the Urban Forest Strategy and other asset management objectives of council. This means that decisions council makes will sometimes conflict with UHI and other objectives of the Strategy. Installation of hard surface infrastructure is one example. Hard surfaces are easier to maintain but can contribute to the UHI effect.

Given these risks, it is important that measures to mitigate the risks are integrated into the Strategy (e.g. appropriate tree species selection; the use of natural surfaces underneath trees).

2.4.3 Hazards associated with increased tree canopy cover

When implementing the Urban Forest Strategy, it will also be important for Council to be mindful of the risks that increased tree canopy cover can pose to the community including:

- the risks that could be posed by trees of certain species or in certain location such as risks of falling trees during storms, falling limbs during extended dry periods or trip and other hazards posed by tree roots;
- the potential for these risks to increase with climate change; and
- approaches to mitigating those risks (e.g. appropriate tree species selection).

2.5 Adaptation options, pathways and timing

2.5.1 Option selected for analysis

In some instances, there may be only one or two feasible adaptation options for addressing the identified climate-related risk or hazard. With respect to the risks posed by extreme heat to the community of Greater Shepparton there are a multiplicity of options available that will help mitigate those risks. Many of those options have already been identified and implemented or are being actively considered as part of the Extreme Heat Complementary-Plan. They include, for example:

- registers of at-risk community members;
- community education and awareness initiatives;
- heat health warnings; a network of cooling places; and
- relief centres.

None of these measures though, are specifically focussed on reducing ambient temperatures. While increased air-conditioning ownership has been identified as protecting people from dying or illness during some heatwaves, ownership is not always enough to protect people in some situations; for example, where people for various reasons have to go outside or are unwilling to use the air-conditioning systems they have. Reliance on air-conditioning may have undesirable consequences including increased peak energy use (and the risk of brown-outs or blackouts), high cost and air quality. Moreover, air-conditioning systems do nothing to reduce ambient temperatures.

Extensive use of water bodies is one option that offers the potential to reduce ambient temperatures, but that option is also unlikely to be feasible for Greater Shepparton given its location and (lack of) water availability.

Another option that might be considered is the extensive use of artificial shading (e.g. shade cloths, shade sails). While this option is probably suitable in specific locations (notably playgrounds, parks and recreation reserves, bus stops and pedestrian crossings), the widespread use of artificial shading is very unlikely to be feasible or cost effective. Similarly, other artificial options, such as treating road surfaces with reflective paint, are designed to reduce urban heat only where alternative cooling strategies, such as tree planting and water features, are not feasible (e.g. Schneider et. al 2023).

Thus, the preferred and arguably only feasible option available to regulate ambient temperatures in Greater Shepparton is large scale planting of trees in urban areas to increase tree canopy cover in a variety of situations across the municipality. Two variants of this option have been assessed for the case study. These are defined as:

Option 1 - continue to implement the Urban Forest Strategy 2017-2037, with the Strategy target of achieving 40% canopy cover in Greater Shepparton by 2037.

Option 2 - continue to implement the Urban Forest Strategy 2017-2037, but with a reduced target of achieving 30% canopy cover in Greater Shepparton by 2037.

In implementing either of these options greater emphasis will be given to ensuring that the heat-health objectives are being met.

As discussed further in section 3.1, in the analysis these options are compared to a Base case of maintaining tree canopy cover at the current level.

2.5.2 Pathways and timing

Climate change projections for the Goulburn region provide a high degree of certainty that the number and intensity of extreme heat days and heatwaves will increase in the future. However, the scale of the increase is still uncertain due to uncertainties about future emission scenarios. There are also uncertainties about the extent of the relationship between heatwaves and adverse health outcomes. Typically, uncertainties of this nature calls for a flexible and adjustable approach to adaptation - ensuring that risks to communities and assets are minimised, while not making unnecessary investments. Flexibility can be achieved by taking a staged or incremental approach to implementing a preferred adaptation option.

With respect to the Urban Forestry Strategy, there is already a great deal of flexibility built into the Strategy as it allows for the incremental increase in tree canopy cover over an extended period of time. This means that outcomes of the Strategy can be periodically reviewed against objectives, with adjustments made to the Strategy as, and if, necessary, including to the timeframe for implementation.

3. Analysis of options

3.1 Overview of approach

The approach applied to the analysis of the adaptation option is a scenario-based cost-benefit analysis (CBA). For the analysis, we have valued a number of heat-health benefits of increasing tree canopy cover. Some other benefits including improved productivity, reduced runoff and the ecological, amenity and recreational benefits of the Strategy have not been valued. Thus, the CBA captures key aspects but not all aspects of Total Economic Value (TEV).

The CBA assessed the costs and benefits of Option 1 (Urban Forest Strategy, 40% canopy cover target) and Option 2 (Urban Forest Strategy, 30% canopy cover target) incrementally to the Base case, with the Base case being the alternative case of not implementing the Strategy and tree canopy cover across Greater Shepparton therefore remaining at its current level of 18.3 %. Economic impacts (costs and benefits) were assessed in an economic model by aggregating discounted annual estimates of each cost and benefit over the analysis timeframe.

The aggregated costs and benefits are expressed for each option as an NPV and a BCR, providing a consistent basis for comparing the options. NPV is the Present Value (PV) of benefits delivered by the option less the PV of costs incurred. NPV measures the expected benefit (or cost) of implementing the policy expressed in monetary terms. The BCR is a ratio of the benefits over the costs. A BCR of 2.0, for example, indicates that the option yields two dollars in return for every dollar spent.

The CBA has been undertaken consistent with the Victorian Guide to Regulation (CBR 2016) and the Economic Evaluation for Business Cases Technical Guidelines (DTF 2013). Major features of the CBA are as follows.

- The analysis is undertaken over a 25-year timeframe from 2024.
- A central discount rate of 4% real is applied, with sensitivity analysis applying discount rates of 2% and 7% real.
- The major costs assessed under Option 1 and 2 are the capital costs (principally tree planting) and operational costs (principally tree maintenance and pruning) of the Strategy.
- The major benefits assessed under Option 1 and 2 are the health benefits of reducing extreme heat linked to increased tree canopy cover. These include avoided mortality and hospitalisations and improved mental health outcomes. Additionally, the health benefits of reduced urban air pollution (NOx, particulates, etc) are also assessed.
- Sensitivity analysis is undertaken to test the effects of changes in key assumptions on results. These include an alternative climate change scenario and changes in estimates of the relationship between tree canopy cover, reduced ambient temperatures and improved health outcomes.

3.2 Results

Results of the analysis are presented in Table 1 and Table 2.

The results are based on the following generic assumptions:

- a 4% real discount rate[4];
- a 25-year analysis period;
- climate projections over the analysis period are based on the moderate climate change scenario (RCP 4.5[5]); and
- all cost and benefit values are in 2024 dollars.

Table 1 CBA results of increasing tree canopy cover to 40% under moderate climate change scenario

Costs and benefits	Option 1 (Increasing tree canopy cover to 40%)
Costs	
Capital costs	$3,639,800
Operating costs	$32,160,900
Total Costs (Present Value)	***$35,800,700***
Benefits	
Avoided health impacts of air pollution	$2,613,200
Value of lives saved	$58,461,300
Avoided healthcare costs	$4,720,500
Increased mental wellbeing	$15,087,200
Total Benefits/Avoided Costs (Present Value)	***$80,882,300***
Net Present Value (NPV)	**$45,081,600**
Benefit Cost Ratio (BCR)	**2.26**

Table 1 shows that Option 1 – Increasing tree canopy cover to 40% by 2037 in Greater Shepparton - will result in an NPV of $45.1 million and BCR of 2.26. This means that every $1 spent on the Strategy will result in a benefit of $2.26. The main driver of this expected outcome is the benefit arising from avoided premature mortality amongst people aged over 65 years, since people aged over 65 years

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4 The discount rate is interest rate used to determine the present value of future cash flows (costs and benefits) in a discounted cash flow (DCF) or cost benefit analysis (CBA). This helps determine if the future benefits from a project will be worth more than the capital costs needed to implement the project in the present.

5 Two climate change scenarios, referred to as RCPs (Representative Concentration Pathways), which are drawn from the IPCC, are used in the analysis. RCP 8.5 is the high emissions growth scenario. This is consistent with the current global emissions trajectory. RCP 4.5 is described by the IPCC as an intermediate emissions growth scenario. This will stabilise emissions growth in the future, but the global temperature will still increase by >2^{0}C above pre-industrial level.

are more susceptible to premature mortality due to extreme heat and heatwaves. Increased mental health wellbeing, avoided healthcare costs (hospitalisations and emergency department visits) and avoided health impacts of air pollution across vulnerable sections of the community are also expected to be significant benefits.

Table 2 CBA results of increasing tree canopy cover to 30% under moderate climate change scenario

Costs and benefits	Option 2 (Increasing tree canopy cover to 30%)
Costs	
Capital costs	$1,955,000
Operating costs	$19,251,300
Total Costs (Present Value)	***$21,206,400***
Benefits	
Avoided health impacts of air pollution	$1,407,800
Value of lives saved	$36,043,800
Avoided healthcare costs	$2,776,800
Increased mental wellbeing	$15,087,200
Total Benefits/Avoided Costs (Present Value)	***$55,315,700***
Net Present Value (NPV)	**$34,109,300**
Benefit Cost Ratio (BCR)	**2.61**

Table 2 shows that Option 2 - Increasing tree canopy cover to 30% by 2037 in Greater Shepparton - will result in an NPV of $34.1 million and BCR of 2.61. The higher NPV but lower BCR of Option 1, compared to Option 2, reflects both greater benefits and greater costs of Option 1, but with the additional benefits of increasing tree canopy cover from 30% to 40% being proportionately less than the additional costs of the increase.

Results for both Option 1 and Option 2 could be conservative because some non-health benefits of increased tree canopy cover have not been valued in the analysis. These include increased productivity, reduced runoff following extreme rainfall events, and the ecological, amenity and recreational benefits of enhanced tree cover. On the other hand, the results do not capture the possibility that improved adaptation measures, such as those implemented through Greater Shepparton’s Extreme Heat Complementary-Plan and Climate Emergency Action Plan, could in part mitigate the health effects of extreme heat in Greater Shepparton in the future. There are also other uncertainties in the analysis, which are discussed further in section 3.4.

Notwithstanding these uncertainties and caveats, it is highly likely that continued implementation of the Urban Tree Strategy will result in substantial net benefits to the community of Greater Shepparton.

3.2.1 Sensitivity analysis

Sensitivity testing has been undertaken on Option 1 and Option 2 to clarify which assumptions can materially change the results. The following sensitivity tests have been undertaken:

- discount rates of 2% and 7%;
- high climate change scenario based on RCP 8.5; and
- lower reduction in observed urban temperature (1 degree Celsius) and extreme heat days due to increased tree canopy cover; and
- higher reduction in observed urban temperature (2.8 degree Celsius) and extreme heat days due to increased tree canopy cover.

Sensitivity analysis results are presented in Table 3. The results show that under all changes increasing tree canopy cover to 40% in Shepparton achieves a positive NPV and BCR greater than 1.

Table 3 Summary of sensitivity and threshold analysis results for Option 1 (BCR)

	Option 1 – Climate change low scenario based on RCP 4.5	Option 1 – Climate change high scenario based on RCP 8.5
Central assumptions – (Discount rate 4%, median reduction in observed temperature and extreme heat days)	2.69	3.00
Discount rate 2%	2.89	3.24
Discount rate 7%	2.41	2.68
Lower reduction in observed temperature and extreme heat days	1.84	2.04
Higher reduction in observed temperature and extreme heat days	3.61	4.05

Sensitivity analysis results for Option 2 are presented in Table 4. The results show that under all changes increasing tree canopy cover to 30% in Shepparton achieves a positive NPV and BCR greater than 1.

Table 4 Summary of sensitivity and threshold analysis results for Option 2 (BCR)

	Option 2 – Climate change low scenario based on RCP 4.5	Option 2 – Climate change high scenario based on RCP 8.5
Central assumptions – (Discount rate 4%, median reduction in observed temperature and extreme heat days)	2.61	2.82
Discount rate 2%	2.77	3.01
Discount rate 7%	2.38	2.56
Lower reduction in observed temperature and extreme heat days	2.05	2.20
Higher reduction in observed temperature and extreme heat days	3.76	4.10

3.3 Further information on assumptions and approach

3.3.1 Assumptions

The following sections set out the key underlying assumptions including assumptions to increases to capital and operating costs required to achieve 40% tree canopy cover by 2037 (Option 1). Other assumptions are listed below:

- Capital costs are based on the current budgeted amount as per the Urban Forest Strategy for Greater Shepparton.
- The modelling assumes that there will be an increase to the operating expenditure to reflect the increased resourcing and effort that goes into planting more trees to achieve the required tree canopy cover by 2037. This increase is in proportion with the required increase to tree canopy cover.
- The model assumes a linear relationship for reduction in number of extreme heat days and avoided annual deaths.
- The model assumes that there will be a linear increase in the urban cooling effect until 2037 as a response to increased tree planting and maximum cooling will be achieved by 2037 and then it remains consistent for the rest of the analysis period.
- To calculate benefits to mental wellbeing due to passive recreation in response to increased tree canopy cover, the model assumes a 5% attribution rate. Attribution rate is the percentage of population that take part in passive recreation due to increased tree canopy cover who otherwise would not have.
- Post-2037, trees will need to be replaced to maintain the tree canopy cover at 40%. The analysis assumes the replacement rate to be about 2% annually of the total stock of trees.
- The model assumes a linear increase in tree canopy as a result of increased planting of trees.

The assumptions listed above also apply to Option 2 (30% tree canopy cover by 2037). Both costs and benefits are significantly lower under Option 2 than under Option 1, although the changes are not directly proportionate to the reduction in tree canopy cover under Option 2 compared to Option 1.

3.3.2 Overview of approach to assessing the effects of tree cover on extreme heat and health outcomes

Using the assumptions above, effects of tree cover on extreme heat days and health outcomes were assessed in the following manner:

- As the number of trees and tree canopy increases linearly, there will be a similar linear increase in the observed cooling. This cooling effect will peak when the tree canopy cover reaches 40% in 2037 and will then stabilise as long as the tree canopy cover is maintained at the same level.
- Under both the climate change scenarios, CC High (based on RCP 8.5) and CC Low (based on RCP 4.5), the number of extreme heat days are projected to increase. However, as the tree canopy cover (and resulting urban heat mitigation) increases, there will be a proportionate reduction in the number of extreme heat days as compared to what would have been if the tree canopy cover remained at 18.3%.
- This reduction in extreme heat days and increase in tree canopy cover leads to a range of benefits. These benefits and the unit value are listed below.
  - Air pollution benefits valued at $7.18 $/tree/year.[6]
  - Avoided premature mortality. Reduced exposure to extreme heat days leads to a reduction in premature mortality amongst vulnerable groups (predominantly people aged over 65 years). Value of life saved is estimated based on the statistical value of a life year (VoLY) of $235,000 (OPBR 2022) and estimated average life years lost per person over 65, which is estimated at 6 years.
  - Reduction in exposure to extreme heat days lead to reduced strain on healthcare as less people will be visiting emergency departments and reduces the strain (costs) on the health care sector. These avoided costs are valued at $3.26 per person/degree/year/day.[7]
  - Increased mental wellbeing. Research indicates that increased investment in greening initiatives for public open spaces such as increasing tree canopy leads to an increase in passive recreation. Passive recreation benefits the user's mental well-being as compared to those who do not take part in passive recreation. Increased tree canopy and green spaces will influence a portion of the general population to take part in active recreation who otherwise would not have taken part in the activity. The model uses a 5% attribution rate to indicate that 5% of the population will be encouraged to take part in passive recreation due to the increase in tree canopy. The benefits are valued at $233.53 per person.[8]

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6 This value is based on the Social and Economic Value Tool (SEVT) developed for Melbourne Water by Marsden Jacob Associates (Marsden Jacob 2023). This value is adjusted for inflation.

7 Based on SEVT and adjusted for inflation.

8 Based on SEVT and adjusted for inflation.

3.4 Uncertainties and gaps in analysis

There are a number of uncertainties and gaps in the analysis. To make an informed decision and understand the modelled benefits these uncertainties and gaps in the analysis must be well understood. The section below outlines some of the key the uncertainties and gaps in the analysis and contains a commentary on whether these uncertainties would impact the results of the analysis.

3.4.1 Increasing tree canopy

The model assumes that under Option 1 a fixed amount, approximately 26,400 trees[9] (which roughly equates to 1.67% of tree canopy) of current top 10 trees[10] (which constitute 46.3% of the assessed urban tree population[11]) will be planted from 2024 until 2037. Under Option 2, the number is approximately 14,200. Simplifying assumptions around tree planting and tree canopy increases were made in the model. The model assumes that with increase in tree planting there will be a proportionate and linear increase in tree canopy annually. In reality, tree growth rates and canopy sizes vary greatly between species. However, incorporating varying growth rates and modelling realistic increases in tree canopy over time would be time-consuming and is out of scope for this study.

While this case study demonstrated the benefits to be gained from increasing tree canopy cover in Greater Shepparton, it does not delve into detail about optimal tree planting strategies. The model assumes that tree canopy increase will be attributed to the increase in number of the current top 10 trees in Greater Shepparton. However, best practice for urban tree populations dictates that the populations of urban trees should contain enough diversity and that no one species should be more than 10% of the population. Accounting for this would change the number of trees required to be planted every year to achieve the tree canopy target.

The location where new trees are being planted is also a key consideration. This has direct impact on the ability of the tree canopy to reduce the Urban Heat Island (UHI) effect. Benefits gained from increasing tree canopy cover in an urban park would be lower than the benefits gained from increasing tree canopy cover over a developed area with buildings and streets. Expected reduction in urban temperatures will be heavily dependent on the locations where new trees are planted, which in turn will depend on a range of factors including availability of suitable urban sites and willingness of the local residents to support trees in their nature strips.

3.4.2 Increase in urban cooling and reduction in extreme heat days

Increase in urban cooling and reduction in extreme heat days are related to each other. As urban cooling increases in relation to improved tree canopy and investments in Blue-Green infrastructure, it directly results in a reduction in observed extreme heat days. This relationship is extremely location specific. As an example, for two places A and B, the same level of tree canopy cover may have differing effect on urban cooling. Best practice to overcome this would be to undertake location

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9 Based on an assumed average tree canopy area for the top 10 species in Greater Shepparton.

10 Urban Forest Strategy, Page 21.

11 As per the Urban Forest Strategy.

specific climate and weather modelling along with modelling the relationship between current observed temperatures in an urban area relative to a non-urban baseline. This will indicate whether there is an observed UHI effect in the location. Further modelling must then be undertaken to establish whether the observed UHI effect is explained by existing levels of tree canopy, proportion of impervious versus pervious surfaces etc. This can then provide a reliable estimation of expected urban cooling from increasing tree canopy cover for the location. However, this approach is complex, time-consuming, and requires specialists.

For this case study, a suitable alternative methodology was developed and used. The alternative methodology involved undertaking a literature review on similar studies and using modelling results from locations with similar weather patterns to Greater Shepparton (such as Perth and Adelaide summer temperatures) as well as from Melbourne. This approach provided an upper, mid and lower bound for expected cooling due to increases in tree canopy cover to 40% (Option 1) and 30% (Option 2) respectively. While sensitivity tests have been undertaken utilising the lower bound for expected cooling[12], it is important to understand that the expected level of urban cooling can vary.

A rough threshold analysis for expected cooling levels in the model indicates that a positive NPV (subsequently a BCR greater than 1) is achieved at cooling levels of greater than 0.5 degrees Celsius achieved through increasing tree canopy cover in Greater Shepparton to 40%. This value is well below the lower bound of 1 degree Celsius utilised in the model and thus there can be a very high level of confidence that investing in increased tree canopy cover in Greater Shepparton will return benefits that outweigh investment costs.

[12] Sensitivity test results are outlined in Section 3.2.1. For all sensitivity tests the analysis returns a positive NPV and BCR greater than 1.

4. Conclusions and next steps

4.1 Conclusions

Extreme heat and heatwaves pose significant risks to the community of Greater Shepparton. These risks are likely to increase in the future under a changing climate. Increasing tree canopy cover through Greater Shepparton's Urban Forest Strategy is likely to result in a range of environmental and social benefits. One of the most significant of these benefits is the potential for extreme heat and heatwaves to be mitigated, especially in urban areas.

The preliminary analysis undertaken for this study indicates that continuing to implement the Urban Forest Strategy and achieving the Strategy target of 40% tree canopy cover by 2037 (Option 1) has the potential to significantly reduce the impacts of extreme heat. This includes reducing the incidence of heat-related deaths in Greater Shepparton by up to 30% by 2050 and reducing the incidence of hospitalisation and emergency department visits. Implementing the Urban Forest Strategy will also result in other health benefits including reduced health impacts of urban air pollution and improved mental wellbeing. Reducing the Strategy target to 30% (Option 2) will result in lower benefits than Option 1 but will still lead to a substantial net benefit.

Notwithstanding uncertainties and gaps in the analysis, it is highly likely that continued implementation of the Urban Tree Strategy will result in substantial net benefits to the community of Greater Shepparton. Our analysis suggests that the higher level of tree canopy cover that will be achieved under Option 1 should continue to be pursued, provided that a 40% target is practically achievable.

4.2 Next steps

A number of steps can be undertaken to ensure that the targeted tree canopy cover of 40% is achieved and in doing so meets the objective of reducing the UHI and associated extreme heat days.

- Ensuring that the number, mix and location of new tree plantings is optimised. A key driver of UHI benefits is tied to the location of tree plantings and optimal mix of trees to provide good canopy cover. For example, planting trees in urban areas with minimal to no cover will provide greater benefits as compared to increasing trees in areas where there is already significant tree cover, especially if those areas are in or close to areas that have relatively high population density and/or significant numbers of vulnerable community members.
- Reducing hard surfaces around trees and replacing them with natural surfaces can increase the survival rate of trees. Where increasing tree canopy cover cannot be increased, replacing hard surfaces with natural surfaces can also have some UHI benefits (Duncan et. al 2019).

Comprehensive community education and engagement on the urban heat and other benefits of increasing tree canopy cover will be important for achieving this objective as it will be for achieving the objectives of the Urban Forest Strategy overall.

- The community information could be enhanced with further analysis of the non-UHI social and environmental benefits of increasing tree cover including the recreational, amenity and biodiversity benefits of enhanced tree cover.

Finally, this case study did not utilise the microclimate model TARGET to estimate the impacts of increasing tree canopy cover on UHI effect and reduction in extreme heat days. Utilising the TARGET model will likely produce more robust values for expected reduction in the UHI cooling effect due to increased tree canopy cover. One possible next step would be to undertake modelling using TARGET to increase confidence in expected urban cooling from increasing tree canopy cover in Greater Shepparton. While this would increase confidence in the results, given that there is already high confidence that the Urban Strategy will result in net benefits, the additional modelling can be regarded as a 'nice-to-have' exercise rather than being crucial.

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