SMART TREES:

Resilience Strategies to Combat Urban Heat Island Effect, Newcastle NSW

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SMART TREES

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

The future livability of urban areas will be dictated by thermal performance, as the effects of climate change begin to make themselves apparent in our day to day lives. In order to mitigate the effects of rising temperatures, our cities need to be retrofitted to their new environment.

This project identified levels of Urban Heat Island Effect (UHIE) experienced across five (5) identified sites in Newcastle's public realm. The temperature data was collected during peak temperature periods in January 2019. This report documents a methodology for using temperature monitoring, which may be conducted manually or by utilising the NCC Smart Pole network. The temperature data recorded from on-site and field based measurement was developed into a series of data visualisations and data spatialisations to interpret and communicate the field conditions with a broad range of audiences. The research team also identified a broad review of mitigation strategies to re-mediate UHIE, and arranged them into a kit of parts to be utilised in consultation with internal and stakeholders. The visualisation techniques and mitigation kit of parts were tested with the Newcastle City Council through three intensive, co-design workshops.

In addition to monitoring temperatures in areas about to undergo redevelopment, the researchers recommend the use of smart data loggers to collect data for POE (Post Occupancy Evaluation) in order to monitor UHIE in new developments. As a priority, sites that warrant POEs should be identified by taking into account demographics where populations are deemed more vulnerable, and public areas that are highly populated in peak summer periods.

SECTION 01.

INTRODUCTION

Introduction 1.0

INTRODUCTION

Smart Trees: Resilience Strategies to Combat Urban Heat Island Effect in Newcastle, NSW

The project team collected a sample set of data pertaining to ambient and surface temperatures over five sites across Newcastle, both urban and suburban. This data was visualised, spatialised and subsequently combined with a range of proposed techniques to mitigate Urban Heat Island Effect (UHIE).

Urban Heat Island Effect is localised warming due to the increase in large amounts of hardscape (materials that absorb and hold heat) as a result of urban development. The sun's heat is absorbed causing the surface and ambient temperatures to increase beyond the anticipated daily temperature. Climate change scientists also predict increases in our average temperatures upwards of 2-3 degrees over the next fifty years, urban centres are under increasing pressure to provide short, medium, and long term resilience strategies for urban heat island effect.

As Newcastle increases in population and built density, the negative impacts of UHIE are expected to become a significant issue facing both the CBD and suburban areas. This project engaged in two areas of the 2017-2021 NCC Smart City Strategy (Smart Governance and Smart Environments), aligning its goals with that of Newcastle's future ambitions as a world leader in Smart City infrastructure and design.

The purpose of this project was to collect temperature data through the peak summer period of 2019 at five sites across Newcastle. The research team then tested various methods of data visualisation and spatialisation, keeping in mind that there are a broad range of audiences within and outside of the council. Through an extensive review of current literature, the project team developed a kit of parts which provided strategies to combat UHIE. The project makes available to the NCC a comprehensive set of tools to replicate this study using smart means, provide information for community consultation, raise public awareness of UHIE and combat increasing temperature in Newcastle's urban environment through the application of various mitigation strategies.

The researchers found that cooling the urban environment can be achieved through the implementation of:

- High Quality Urban Design
- Better Performing Materials
- Increased and Diversified Urban Vegetation
- Reduction in Localized emissions from transport and energy uses

The following report is a detailed documentation of the project and will be available both digitally, which is the most appropriate means for disseminating and engaging with the techniques developed, and as a printed document which may suit other audiences or those who do not have access to digital means.

UHIE 1.1

UHIE SUMMARY

Urban Heat Island Effect is localised warming a s a result o f urban development due to to the increase in the large amounts of paved and dark coloured surfaces like roads, roofs and car parks. The sun's heat is absorbed and retained causing the surface and ambient temperatures to rise. Anthropogenic heat production, such as the heat produced through car engines and air conditioners also contribute to Urban Heat Island Effect (UHIE). One key feature of UHIE is the difference in ambient and surface temperatures, on average, surface heat ranges from slightly above air temperature in the shade to between 1 to 20 degrees Celsius above air temperature in sunlight, depending on the intensity of sunlight and material properties (Rosenzweig and Solecki 2006; EPA 2008). This vast difference in what is recorded and distributed as the daily temperature versus the reality of the physical surface temperatures may lead to individuals unknowingly placing themselves in extreme heat conditions.

This increase in ambient and surface temperature poses a serious health risk to humans, animals and has crippling impacts on infrastructure. The combination of increasing amounts of paved/hardscape surfaces in urban areas compounding with the affects of climate change can lead to extreme heat events. In the 2016 'Minimizing the impacts of extreme heat: Guide for local government' NSW Office of Environment and Heritage and Adapt NSW defines extreme heat as the following:

> *"Extreme heat is defined as significantly hotter and/or more than average summertime temperature for a location, whereby human and animal health, and the performance of infrastructure and the delivery of services may be adversely affected. This includes, but is not confined to heatwave conditions"*
> (NSW Government, 2016)

Further, the guide indicates that by 2070 NSW will experience on average 26 more 'hot' days than current. Based on this prediction, and with the knowledge that as extreme heat event occurrences rise in frequency and intensity so do the associated risks, it is estimated that annual net temperature related deaths will increase by 1250 deaths by 2070, and 8628 deaths in 2100, nationally. This figure alone is cause for great alarm, currently extreme heat kills more Australians than any other natural disaster. (Coates, 2014)

Pinpointing the aspects of urban design that are direct causes of increased temperature is the natural first step when seeking to mitigate this issue. Drawing on previous investigations into UHIE, specifically ' Moreland City Council's UHIE action plan ' For a cooler, greener, more livable city', several driving factors for UHIE that serves as a springboard for Newcastle's analysis of current urban conditions include:

1. **HARDSCAPE: having a high percentage of solid surfaces e.g. asphalt, concrete, paving** - These surfaces absorb, trap and re-radiate heat. They also prevent rainwater soaking in, reducing water available for plants, which in turn reduces evaporative cooling.
2. **LACK OF GREEN: Limited vegetation** - reduces shading and cooling through evaporation from plants through their leaves, reduces the ability for humans and animals to inhabit public space.
3. **DEVELOPER DRIVEN DESIGN: Urban development pressure** - creates denser environments that trap heat, vehicle focused areas that do not cater for pedestrians and removal of green areas reducing cooling.
4. **MATERIALITY: Construction materials which hold heat and have low reflectivity** - e.g. terracotta tiles, bricks, bitumen and concrete - these materials absorb, trap and re-radiate heat.
5. **POORLY PLANNED DENSITY: dense urban arrangements** - absorbs and traps heat with little consideration of breezeways and green pockets.
6. **INFRASTRUCTURE: Heat production from activities of people** - produced by vehicles, split air conditioners, construction. Etc.
7. **POLLUTION: Air pollution** - that creates a local 'greenhouse' effect, trapping heat.

(Moreland City Council 2016)

The areas that an be improved though the mitigation of UHIE can be broken down into the following categories which will be further discussed in the following section: Dangers and Impacts. These factors are:

- **Social/Health**: reduction in heat related illness and fatality, increases in outdoor activity and improvement in mental wellbeing.

- **Economic**: reduced energy costs as a direct result of reduced use of artificial cooling, increased property values and increased retail spending in commercial areas.

- **Environmental**: cleaner, healthier waterways, reductions in air pollution and dust, more water retention in the landscape in a water constrained climate, healthy flora and fauna.

DANGERS + IMPACTS

UHIE can trigger a range of dangerous situations and has broad reaching and significant social/ health, economical and environmental impacts.

SOCIAL/HEALTH IMPACTS

Socially, there are very real physical dangers that are posed by exposure to extreme heat. Those most vunerable in Australia are the following groups: Over 65's, young children, socio-economically disadvantaged groups, outdoor workers, older people living alone, those who aren't fluent in English and disabled people.
The dangers and consequences of UHIE on the above user groups are;

- Illness: Dehydration, Sunburn, Heat Cramps, Heat Exhaustion, Heatstroke, Asthma/ Respiratory issues. These health risks increase in severity once temperatures exceed 32 degrees celsius ie. 32 - 40 degrees: heat cramps and exhaustion
  40 - 54 degrees: heat exhaustion and heatstroke
  54 degress > heatstroke and possible fatality
- Fatality: In extreme instances, exposure to heat can result in death. A 2006 study of temperature related deaths in rural Victoria found that a sustained temperature above 32 degrees (9am -9am) resulted in an 18% increase in mortality rates. (Monash Climate School of GES, 2006)In 2003, Europe experienced an extreme heat wave that resulted in an estimated 50,000 deaths. (Argaud et al, 2007)
- Wellbeing: When urban spaces are unshaded/percieved to be 'hot' zones, vunerable groups are more likely stay within their homes, this loss of public amenity can have severe social, physical and mental impacts.
- Behavioural: High temperatures have been linked to an increase in aggressive crimes, such as civil unrest, high levels of street violence, attacks and homocide, road rage and domestic violence.

ECONOMICAL IMPACTS

Increasing heat in urban centres leads to greater energy consumption as air conditioners are utilised to combat UHIE and maintain optimal temperatures within buildings for inhabitants. Urban infrastructure is also vunerable to heat, and is prone to failure/damage in high temperatures resulting in a disruption of services and potentially triggering health risks.

The economical impacts of UHIE are as follows:

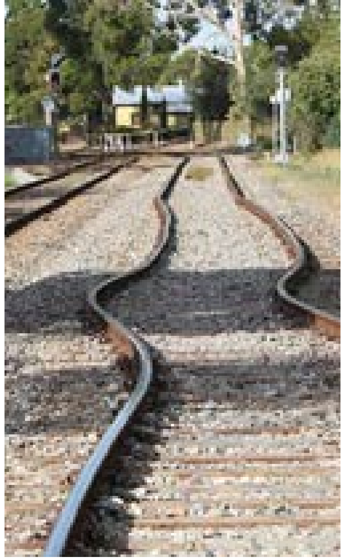
- Power shortages: Peak energy use spikes, network failure, overloads.
- Transport infrastructure failures: Buckled train lines, failures of air conditioning, eletrical faults, delays, deterioration in bitumen.
- Lowering of realestate values, reduced consumer spending in urban areas, lower attendance at public events.
- Indoor or Outdoor work unable to be completed: SafeWork NSW states " If a worker thinks their workplace is too hot, they should report it. A worker may cease, or refuse to carry out, work if they have reasonable concern the work will expose them to a serious risk to their health and safety." (SafeWork NSW, 2019).

ENVIRONMENTAL IMPACTS

The environmental impacts of UHIE are both long and short term and can lead to dangerous conditions for humans, animals and infrastructure.

The dangers/environmental consequences of UHIE are:

- Air Quality: Extreme heat can exacerbate air quaility issues such as pollution from bushfires, car exhausts and industrial fumes as well as increased levels of ozone. A lack of breeze can allow pollution to stagnate, and prolonged dry conditions increase rates of dust and pollen and may lead to bushfires.
- Water quailty: Surface Warer can be impacted by extreme heat events - outbreaks of algal blooms
- Affects to ecosystems and wildlife: increased heat can shift precipitation making vegetation sickly and prone to bushfire. It can also push species outside of their temperature comfort zones, resulting in mass deaths or migrations to unsuitable urban spaces.
- Bushfires: causing the destruction of both urban and environmental systems.


Buckled train tracks at Noarlunga line in Adelaide, Bitumen Melting on Oxley Highway, ABC News
Newcastle Sunrise during Heatwave, Dave Anderson, 2018

LITERATURE REVIEW

This report is underpinned by an extensive review of the existing literature on Urban Heat Island Effect. In particular there was a thorough investigation into Australian examples of best practice, particularly focused on reports and strategies devised by Council's, Local Government, State Government initiatives and methods.
Some of the key findings and central texts that informed this research will be briefly explored in this chapter, however for the full documents/texts please see APPENDIX C. Literature Review. The following is a brief summary of four documents and how they informed our research efforts:

Moreland Urban Heat Island Effect Plan: For a Cooler, Greener More Livable City.
Moreland City Council, 2016

This long term action plan was created to mitigate UHIE in the Moreland City LGA. Written for a civilian audience, it defines UHIE and provides explanations to potential methods of reducing the effects. This document pinpoints the triggers for UHIE, listing key factors and compliments this with a list of feasible measures that will reduce the effects.
They identify the following:

- Vegetation:
  - Increase vegetation and protect existing
  - Increased outdoor landscaping, Green walls and roofs
  - Improve parkland and open space (irrigated spaces)
- Water:
  - Water Sensitive Urban Design
  - Materials:
  - Use of reflective materials
- Urbanisation
  - Street Design - orientation, width
  - Evaporative air coolers
  - Public Transport
  - Improve building quality to reduce the need for artificial cooling
- Social
  - Social UHIE policy and education.

(Moreland City Council 2016, p6).

This report provides the base level information with which the Smart Trees Kit of Parts and Matrix was developed, it further identifies economic, social and environmental issues that arise from UHIE, which greatly informs the gravity of the situation in Newcastle. It further identifies a series of targets/goals that Moreland City Council has committed to achieving, such as "Increase vegetation in Moreland's most vulnerable areas by 35% by 2020; Stormwater harvesting infrastructure supplying 30ML/a of treated water for open space irrigation by 2020" (Moreland City Council 2016, p22).

Temperature Thresholds Associated and Increased Mortality in Ten Major Population Centers in Rural Victoria, Australia
Monash Climate School of Geography and Environmental Science, 2006

The research examines whether similar mortality temperature thresholds that apply to urban centers are applicable in rural settings. Providing a clear and concise view of the relationship between increased and sustained temperatures and mortality. The identification of **32 degrees** as the mean temperature that should be used as a base heat alert for this region greatly informed the assesment of what should be considered a 'danger zone' for Newcastle. This report found that days with temperatures above this threshold (9-am-9am, 32 degrees) are associated with a median mortality increase of 18%.

Cooling the Commons: Pilot Research Report
Mapping Urban Resilience in Riverland Sydney (MURRS) - Western Sydney University - Institute for Culture and Society, 2018

This study reviewed factors that produce urban heating in Sydney's rapidly developing urban fringe and the key socio-environmental issues. These include the health effects of extreme heat and research highlighting the dearth of information about how residents navigate and traverse public space and interact with the physical environment.
The concept of 'cool commons' was employed to identify those spaces that offer cooler temperatures than surrounding areas and that are used by, and accessible to, the vulnerable members of the community. The working hypothesis encouraged a focus on identifying these 'commons' and an emphasis on funding going to supporting and encouraging this commoning, rather than spreading focus broadly across entire suburbs. (MURRS, 2018. p3)
Ideas around 'cool commons' are particularly relevant to the Wallsend Library site, which acts as a refuge for the community in extreme weather events. Once a space has been identified as such, the MURRS report highlights the need to consider public transport infrastructure that allows users to safely access these 'commons'.

Where Should All the Trees Go? State buy State -Victoria
University of Western Australia, 2017

This report acts as a state specific analytical overview on canopy loss, communities vulnerable to heat related stresses and potential for future canopy tree planting. Through graphic representations it outlines percentages of canopy cover vs hard surfaces in VIC, identifying areas of greatest vulnerability and states that these areas have the potential to be prioritised for revegetation or urban cooling strategies.


Minimising the impacts of extreme heat
A guide for local government
WESTERN SYDNEY UNIVERSITY
Cooling the Commons
Pilot Research Report
UNIVERSITY OF WOLLONGONG
8.0
Urban Ecology
VICTORIA
COOL IT
ADDRESSING HEAT VULNERABILITY IN REGIONAL VICTORIAN TOWNS
URBAN FOREST STRATEGY
2017-2037
Final Report
Responding to the Urban Heat Island: A Policy and Institutional Analysis
Temperature thresholds associated with increased mortality in ten major population centres in rural Victoria, Australia
Moreland Urban Heat Island Effect Action Plan

SECTION 02.

DATA

Data Collection 2.0

INTRODUCTION

DATA COLLECTION+ PROJECT SITES

In order to build a wide ranging perspective of UHIE in Newcastle, the data collection phase involved the establishment of study sites and the collection of data from those sites. In this project, five sites within the NCC Local Government Area (LGA) were selected as identified on the following map.

These were:

1. Watt Street, Newcastle, 2300

2. Worth Place, Newcastle, 2300

3. Newcastle Interchange, Wickham, 2293

4. Wallsend Library, Wallsend, 2287

5. Beresford Avenue, Beresfield, 2322

This chapter will detail the results from these five locations. At each site, a series of 8-10 data collection points were nominated. For Site's 1-3, existing 'smart poles' locations were assigned as data collection points. At Site's 4 and 5, various site locations were chosen for readings in the absence of 'smart poles' at these sites.

The Smart Trees research project's data collection phase initially intended to collect the temperature data from Newcastle City Councils new smart pole network. However, the time lines for the installation of the temperature sensors in the smart poles did not overlap with the peak summer temperature period required for the data set. As a consequence, the research team manually collected the data. The data recorded included surface temperature readings and ambient temperature readings. Surface readings were taken using a noncontact laser thermometer tool, and ambient measurements were taken on a wireless twopiece thermometer kit.

Following establishment of the study sites and measurement points, the data was recorded over the month of January 2019. Readings were taken around 8am, 12pm, 5pm, and 10pm on measurement days (range of 12-16 measurement days varying for different sites). These times are listed over the course of this report as the following segments: Morning, Midday, Afternoon and After dark.

The following section will detail the methods taken to acquire, input and analyse the data:

Map of Newcastle detailing site locations; image sourced from NearMaps

METHODOLOGY

METHODOLOGY

This section aims to outline the methodology pertinent to data handling in the Smart Trees UHIE Study. The data handling process entailed a series of stages including:

1. Data Acquisition
2. Data Input
3. Data Analysis

Each stage is detailed throughout this section, such that the Newcastle City Council (NCC) can delineate and replicate this methodology should they wish to continue or extrapolate on this research.

DATA ACQUISITION

The data recorded included surface temperature readings and ambient temperature readings. Surface readings were taken using a non-contact thermometer tool, and ambient measurements were taken on a wireless two-piece thermometer kit. These items were purchased from the electronics retailer Jaycar. The below image depicts the model of non-contact tool (a) and wireless thermometer kit (b) used in this study.

In application, both tools proved simple to use. The non-contact tool functions by holding a trigger and pointing the tool at the location of choice. A laser aids the user to visualise where the tool is pointing. The resultant temperature measurement is depicted on the liquid crystal display (LCD) screen on the rear of the tool to 0.1oC accuracy.

The wireless thermometer kit is a battery powered continuous running pair of devices. As such, measured temperatures can be readily viewed on the display component of the kit to 0.1oC accuracy. The kit is considered most accurate when the two components are separated by a minimum distance of 1.5 m, and are allowed at least 30 min to equilibrate at a new location.

Through use of the tools outlined, surface and ambient temperature data was acquired over the month of January 2019. Readings were taken around 8am, 12pm, 5pm, and 10pm on measurement days (range of 12-16 measurement days varying for different sites).

DATA INPUT

Readings taken during this study were recorded using personal phones and tablets supplied by the University of Newcastle . The devices employed did not possess the ability to send or store data, hence readings from the units were viewed and then separately recorded. The UON team was equipped with Apple iPads that had cellular capabilities. Given this, the team was able to take readings in-situ and instantly upload results into an online Excel file.

Although future studies will undoubtedly utilise the smart pole temperature loggers to acquire data, the physical presence of the researchers on the site greatly increased the teams' understanding of the effects of UHIE, and created a broader understanding of the sites in question. As UHIE is generally a human-made issue, that predominantly affects human beings it is pertinent to remain physically connected to the data in some way at all stages.

DATA ANALYSIS

Data obtained within this study was input into an Excel template designed to convey data from day today. The structure used provided ease in viewing and ease in handling of the data. An example of the Excel template is presented on the following page.
This template illustrates the data layout used by the UON research team. Surface and ambient (Air) temperature readings taken on the same day and between days can be readily viewed through this arrangement. By use of this, average 8am, 12pm, 5pm, and 10pm temperatures at each data collection point were established. This involved preparing a separate form of summary table that contained data recorded throughout the project.

In order to separate each sites' data into ambient and surface temperatures the following tables were developed for both surface and ambient temperature for all locations at each site.
For the full and comprehensive data set across all sites, please see APPENDIX B: Data Set.

DATA ANALYSIS: EXAMPLES OF EXCEL SPREADSHEETS

Site X																			
Date	Temperature Readings (°C)																		
Date 1	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		
Time	Surface (Grass)	Air	Surface (Grass)	Air	Surface (Grass)	Air	Surface (Concrete)	Air	Surface (Asphalt)	Air	Surface (Asphalt)	Air	Surface (Asphalt)	Air	Surface (Asphalt)	Air	Surface (Asphalt)	Air	
Time 1	20.2	20.9	20.4	20.9	20.1	20.9	19.0	20.9	19.2	20.9	20.2	20.9	20.7	20.9	20.3	20.9	20.7	20.9	(Rainy day)
Time 2	34.6	26.5	34.1	26.5	31.9	26.5	27.3	26.5	28.4	26.5	29.0	26.5	34.2	26.5	35.8	26.5	33.2	26.5	
Time 3	32.1	26.5	32.1	26.5	31.6	26.5	24.6	26.5	26.1	26.5	28.0	26.5	31.3	26.5	31.9	26.5	31.3	26.5	
Time 4	25.6	23.2	25.4	23.2	24.9	23.2	23.6	23.2	23.3	23.2	24.5	23.2	25.2	23.2	25.3	23.2	24.5	23.2	
Date 2	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
Time 1																			(Sunny, 28/21)
Time 2																			
Time 3																			
Time 4																			
Date 3	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
Time 1																			(Sunny, 30/22)
Time 2																			
Time 3																			
Time 4																			
Date 4	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
Time 1																			(Cloudy, 27/21)
Time 2																			
Time 3																			
Time 4																			

Surface (Location 1)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-07	1	28, 21	20.2	34.6	32.1	25.6
Jan-08	2	28, 21	0.0	0.0	0.0	0.0
etc.	etc.	30, 22	0.0	0.0	0.0	0.0
Average Temp. (°C)			6.7	11.5	10.7	8.5

Ambient (All of Site X Locations)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-07	1	28, 21	20.9	26.5	26.5	23.2
Jan-08	2	28, 21	0.0	0.0	0.0	0.0
etc.	etc.	30, 22	0.0	0.0	0.0	0.0
Average Temp. (°C)			7.0	8.8	8.8	7.7

Sample Excel Spreadsheet for Data Input and Analysis(TOP),
Surface and Ambient Temperature Excel Spreadsheet for Site X Location 1 (BOTTOM LHS,

Visualisation 2.1

INTRODUCTION

VISUALISATION: SCATTER GRAPHS

In order to increase the legibility of the data, the research team explored visualisation techniques of the collected temperatures across the five sites.

Once the measurement period concluded, the research team then transposed the raw temperature data into a series of excel spreadsheet generated graphs, highlighting the four separate measurement times across the 12-16 day period. These 'scatter' graphs are accompanied by a location map highlighting the 8-10 data log locations, and a panorama image that seeks to clarify the site conditions and orientate the user. The following visualisations represent the entirety of the data collected.

Through the process of visualising the data, indications of peak temperature periods within the days cycle become apparent, as does the impact of materiality on the surface temperatures collected. These graphs provide an easily replicated and reasonably accessible data set that could be linked to live data feeds from the smart pole network in the future. As a part of our briefing meetings with the NCC Smart City team and other pertinent council team members, we understood that low-end software which is readily available such as Microsoft Office, is preferable to specialised platforms for repeatability and capability of internally generated visualisations.

While the graph format provides some clarity as to the conditions currently existing on the selected sites, for the purpose of this project it remains a somewhat inaccessible format to several of the more vulnerable user groups highlighted in the initial UHIE summary.

Providing site maps / plans adjacent to the graphs are useful to those users trained in this means of visualising information, however these required further development through spatialisation to become a more fully accessible means of communication to deliver information regarding UHIE to constituents of NCC.

The following is a comprehensive visualisation of the data collected across the five sites.

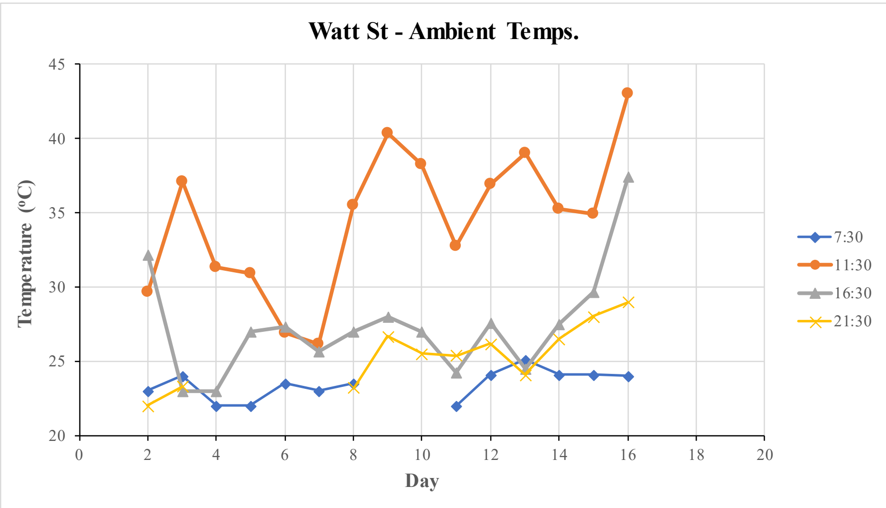
WATT ST: SITE INFO + AMBIENT TEMPERATURE

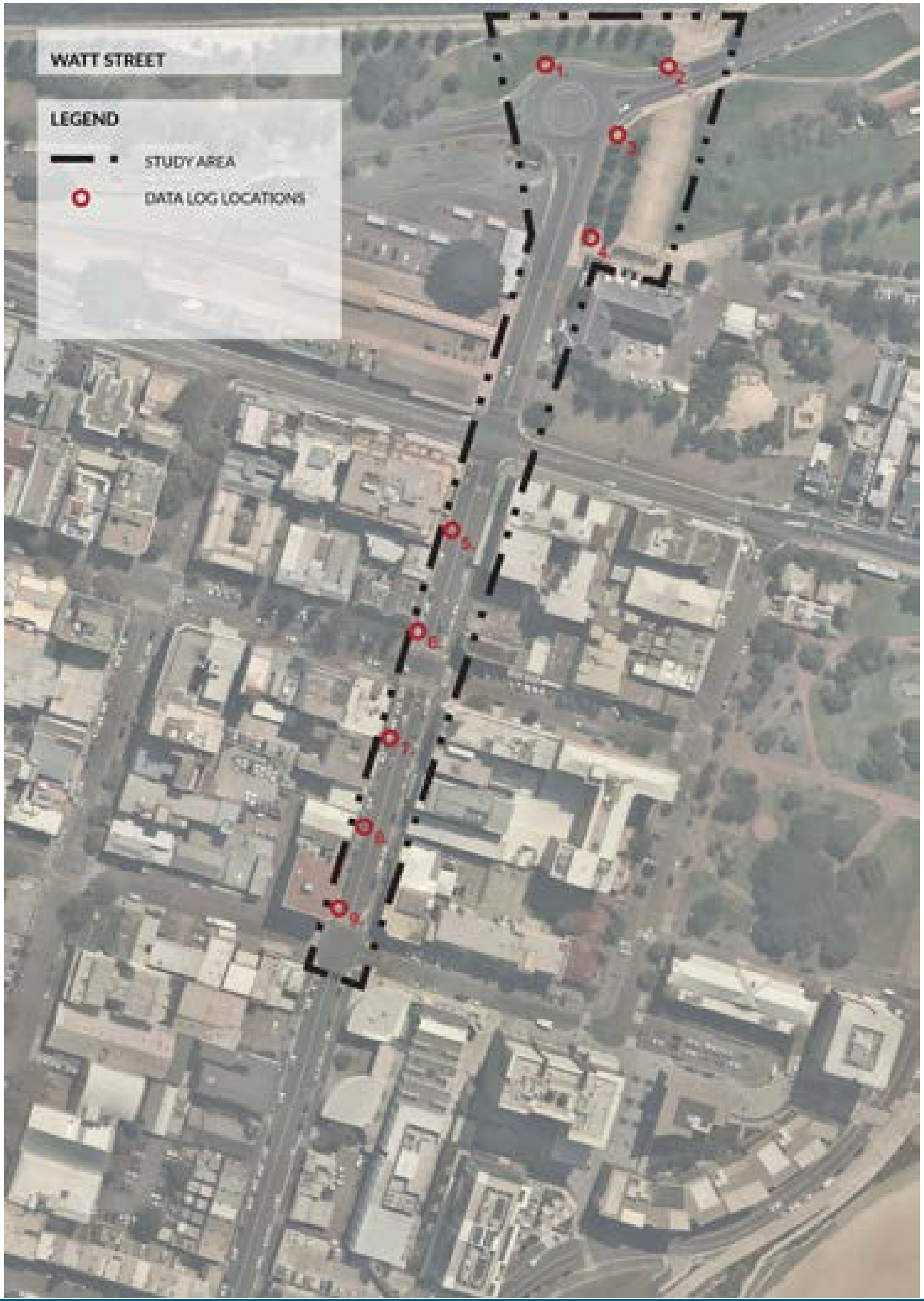
1. WATT STREET

The ambient and surface temperatures of Watt Street were recorded at 9 data log locations, as depicted in the accompanying map to the right hand side of the page. The panorama image below captures the urban conditions of the locations measured.

The following pages reflect the data log location conditions and the data collected, both in its raw temperature form, and visualised as a simple graph, illustrating the four measurement periods: Morning, Midday, Afternoon and After Dark. The graph on this page is the ambient or air temperatures across the full period of data collection. The pages following are the surface temperatures.

WATT STREET AMBIENT TEMPERATURES





 Watt St Panorama (left); image credit Jedidiah Cranfield, Watt St data log locations map (right); image source NearMaps

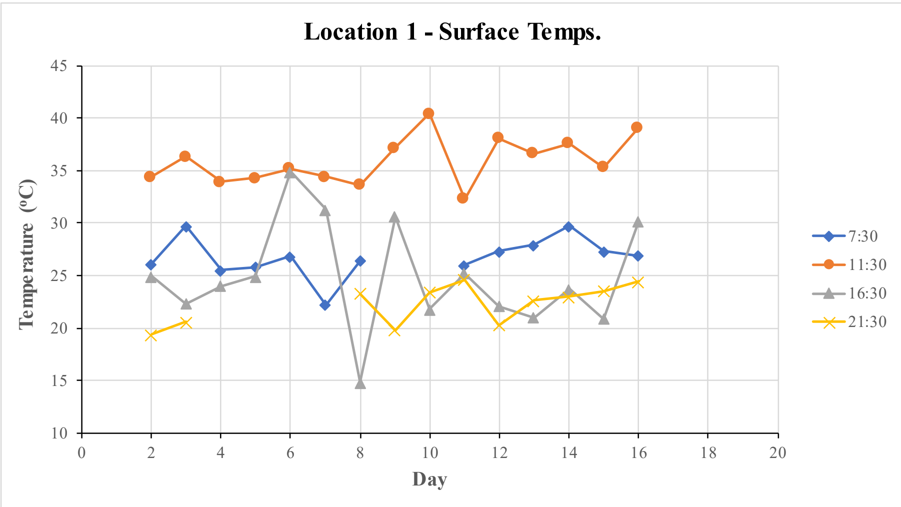
WATT ST:
SURFACE TEMPERATURE

WATT STREET - PHOTOGRAPHS AND SCATTER GRAPHS

Through manual collection methods the research team physically collected data from the base of the smart poles located along Watt Street. The accompanying image highlights the materials present at each log location, providing an palate that informs the surface temperatures collected.

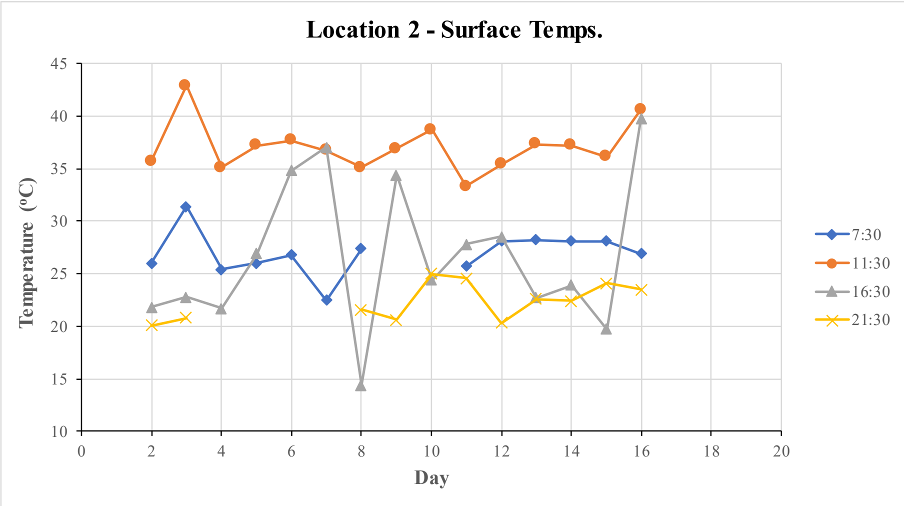
The following pages provide the surface temperatures across the 16 day measurement period recorded at the Watt Street Site.

LOCATION 1 SURFACE TEMPERATURE DATA

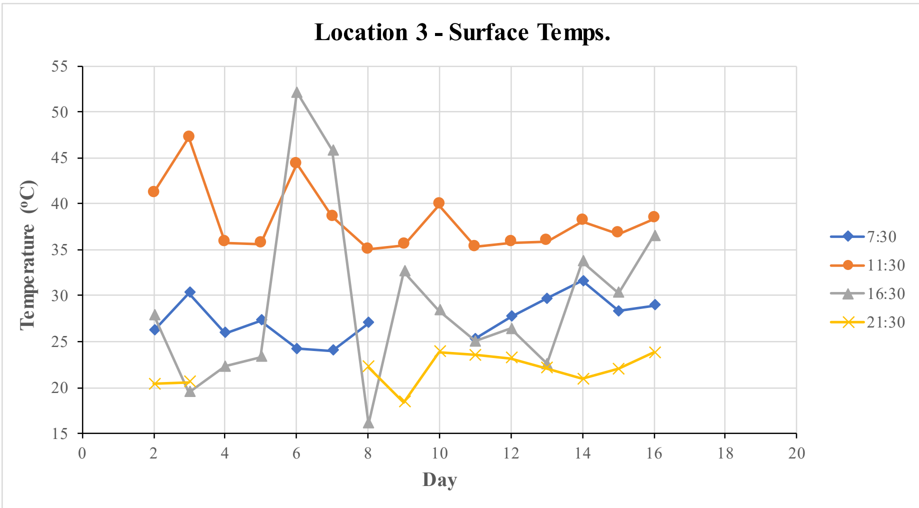


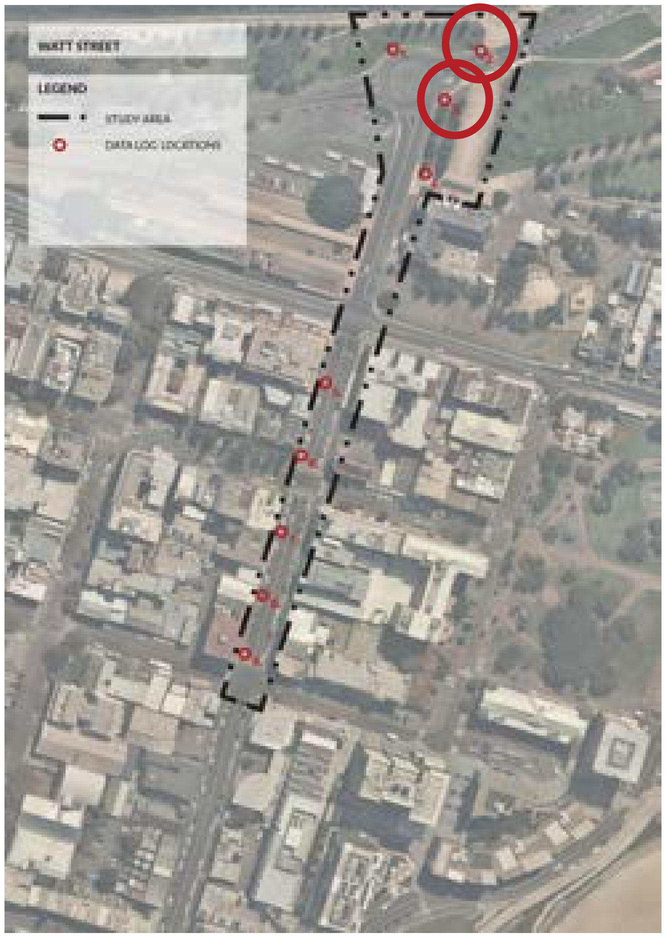
WATT ST:
SURFACE TEMPERATURE

LOCATION 2 SURFACE TEMPERATURE DATA



LOCATION 3 SURFACE TEMPERATURE DATA

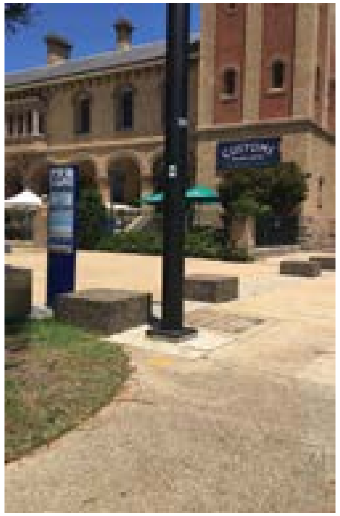


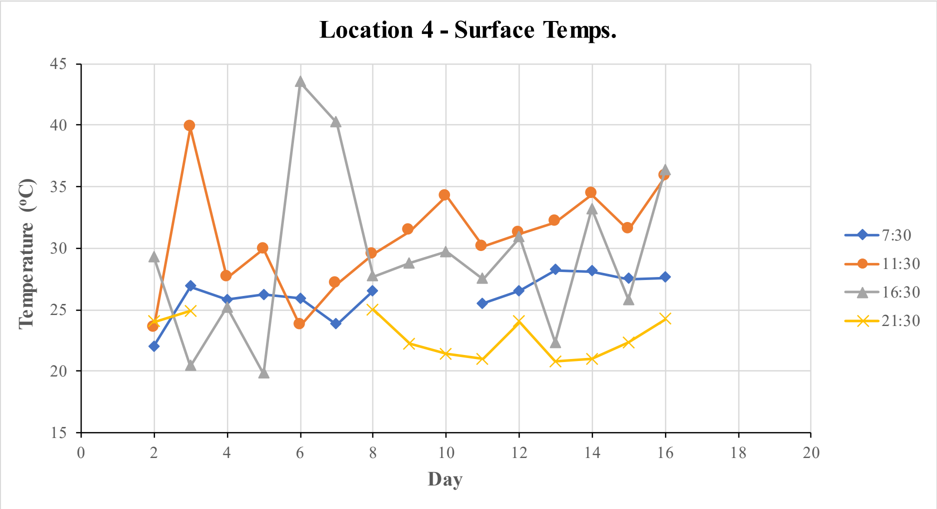


 Watt Street Surface Temperature Data Locations 2 + 3:
Log Location Image, Raw Data and Graph

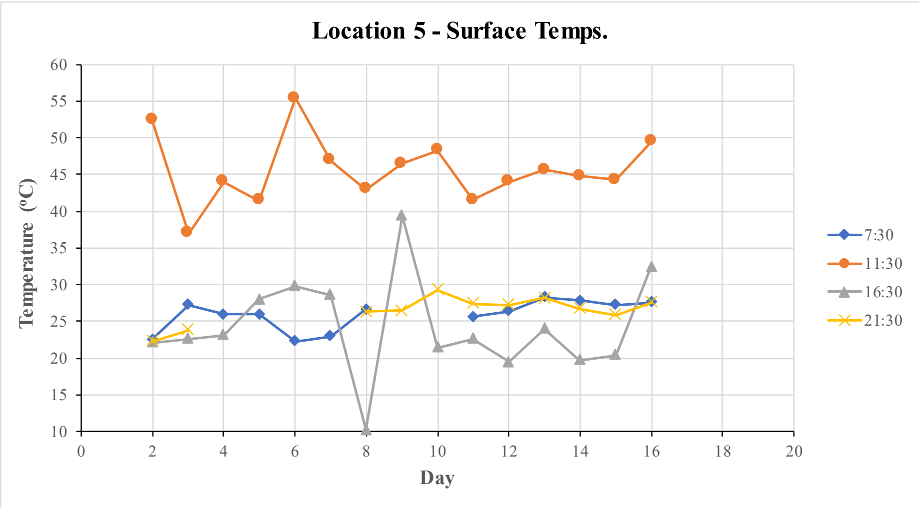
WATT ST:
SURFACE TEMPERATURE

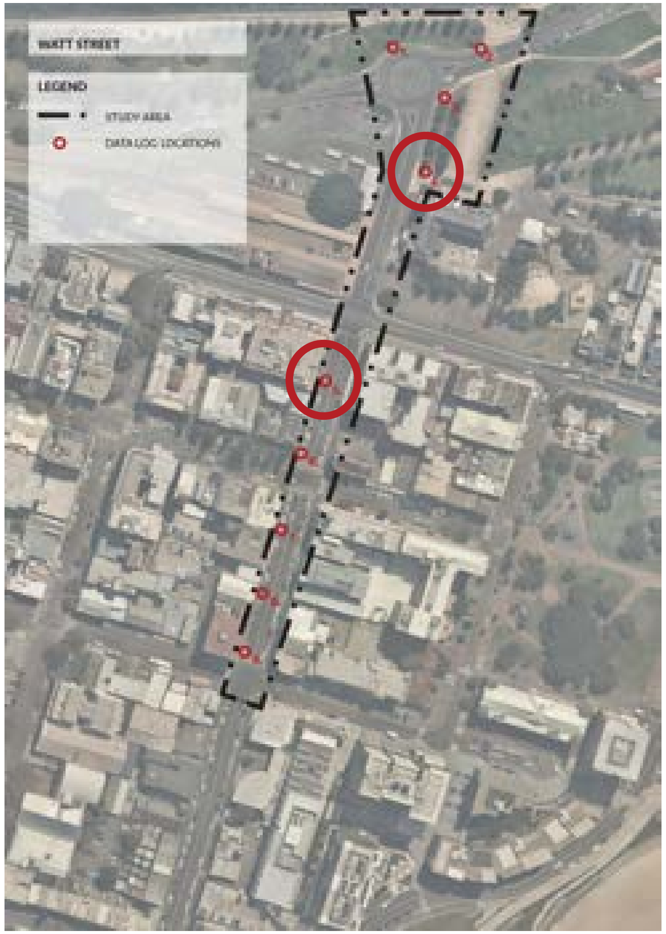
LOCATION 4 SURFACE TEMPERATURE DATA





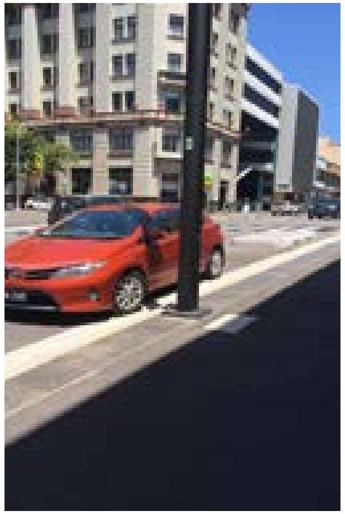
LOCATION 5 SURFACE TEMPERATURE DATA

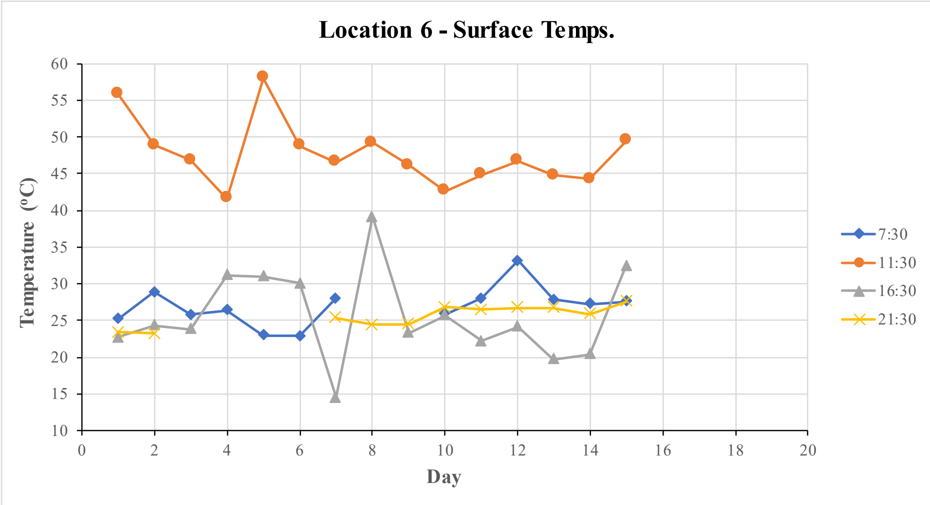




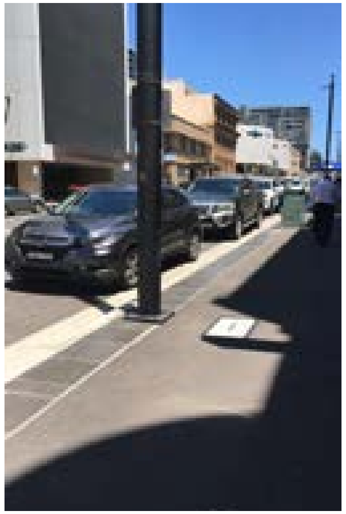
WATT ST:
SURFACE TEMPERATURE

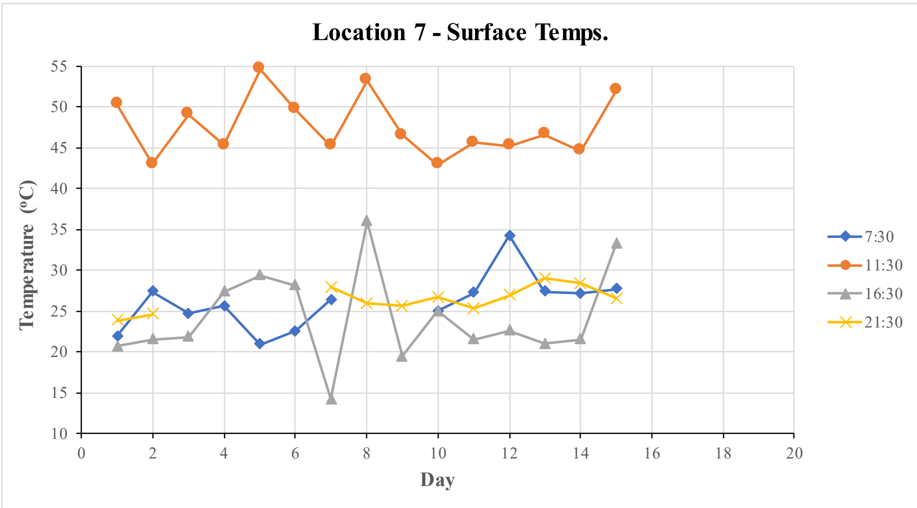
LOCATION 6 SURFACE TEMPERATURE DATA

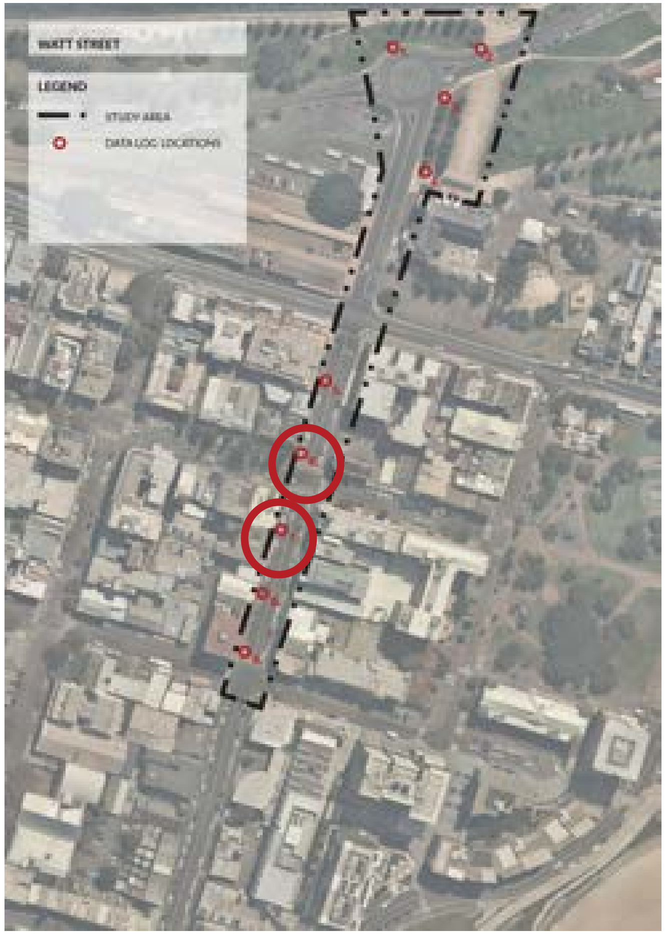




LOCATION 7 SURFACE TEMPERATURE DATA



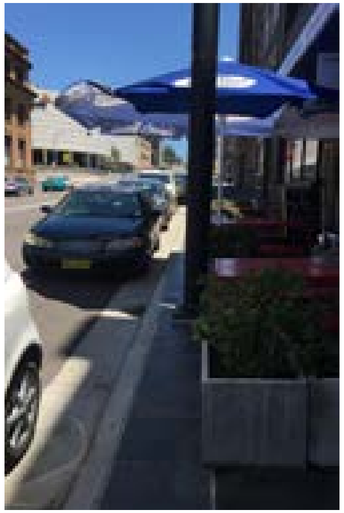


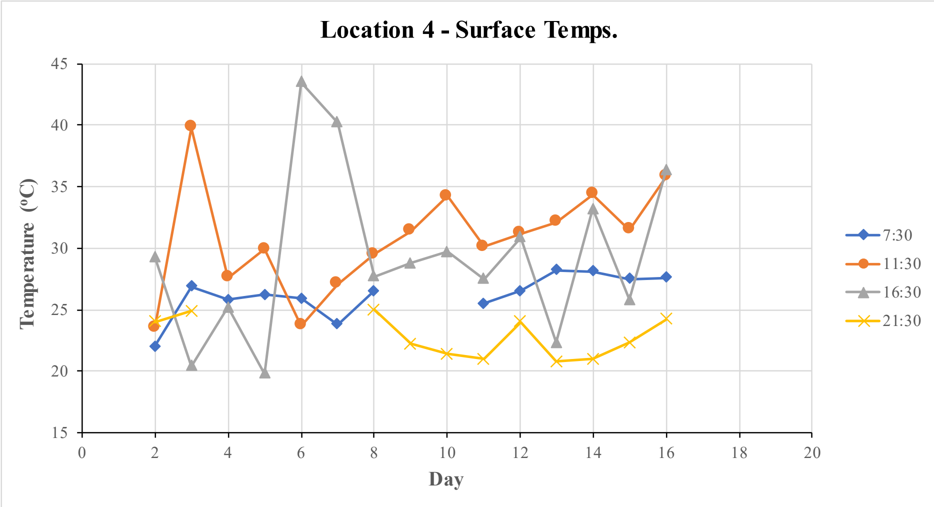


 Watt Street Surface Temperature Data Locations 6 + 7:
Log Location Image, Raw Data and Graph

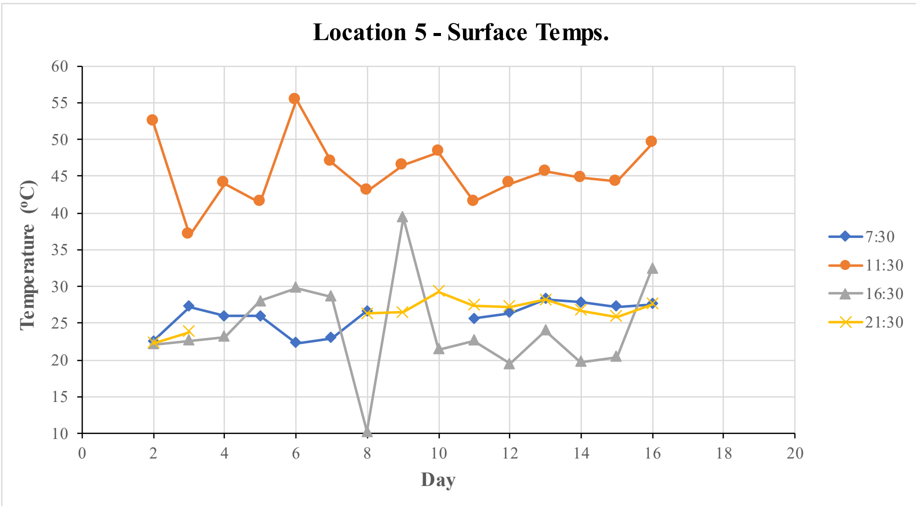
WATT ST:
SURFACE TEMPERATURE

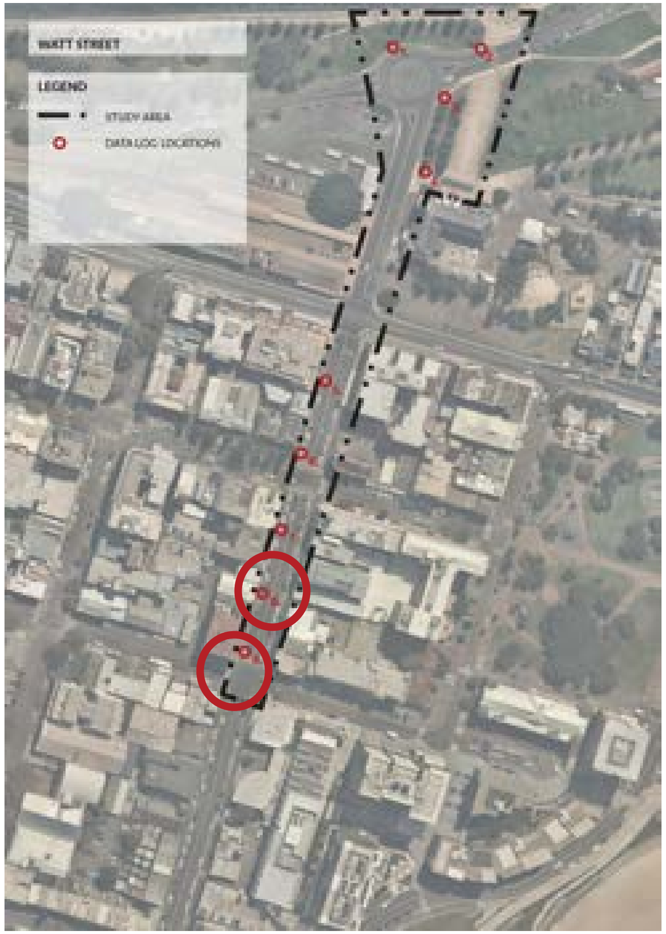
LOCATION 8 SURFACE TEMPERATURE DATA





LOCATION 9 SURFACE TEMPERATURE DATA





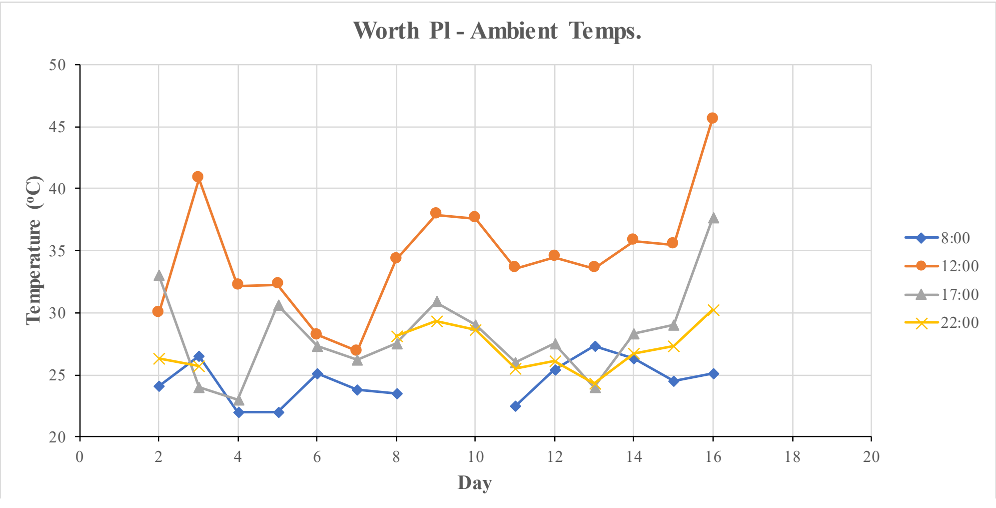
WORTH PLACE: SITE INFO + AMBIENT TEMPERATURE

2. WORTH PLACE

The ambient and surface temperatures of Worth Place were recorded at 10 data log locations, as depicted in the accompanying map to the RHS of the page. The panorama image below captures the urban conditions of the locations measured.

The following pages reflect the data log location conditions and the data collected, both in its raw temperature form, and visualised as a simple graph, illustrating the four measurement periods: Morning, Midday, Afternoon and After Dark. The graph on this page is the ambient or air temperatures across the full period of data collection. The pages following are the surface temperatures.

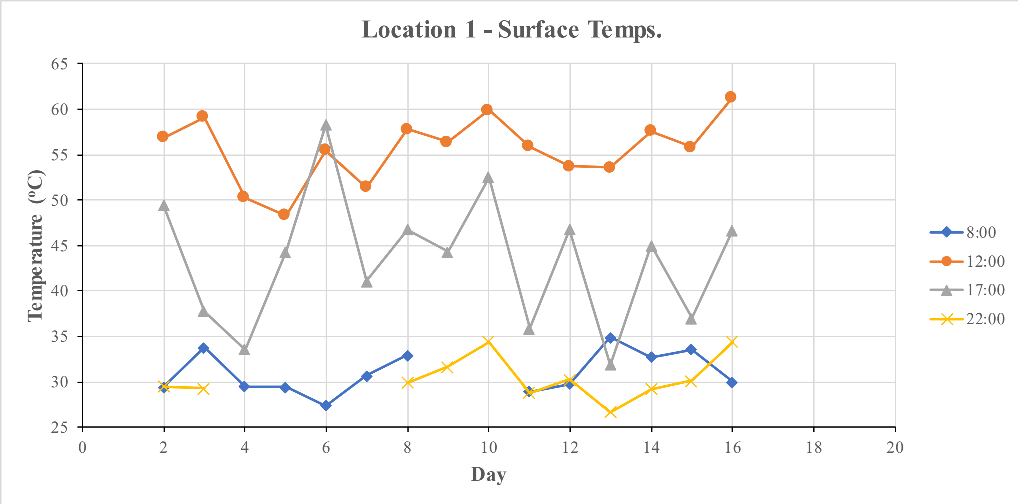
WORTH PLACE AMBIENT TEMPERATURES



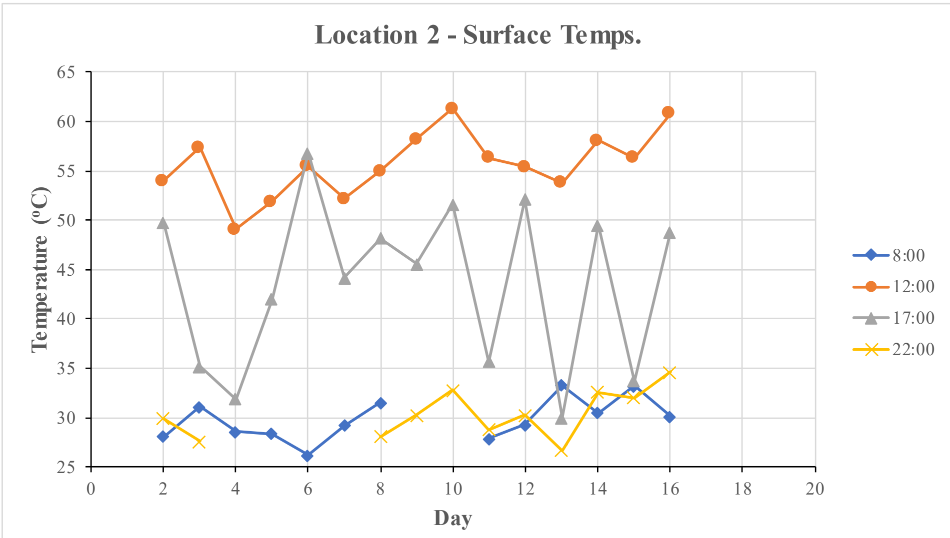
 Worth PlacePanorama (left); image credit Jedidiah Cranfield, Worth Place data log locations map (right); image source NearMaps

WORTH PLACE:
SURFACE TEMPERATURE

LOCATION 1 SURFACE TEMPERATURE DATA

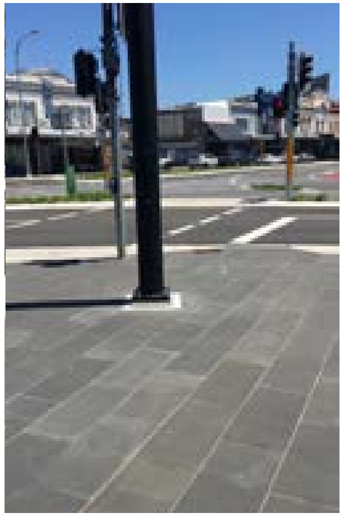


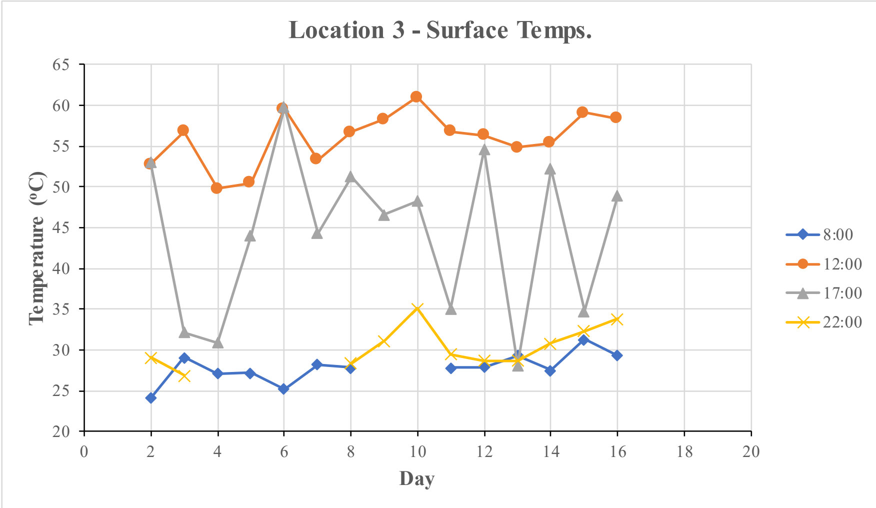
LOCATION 2 SURFACE TEMPERATURE DATA



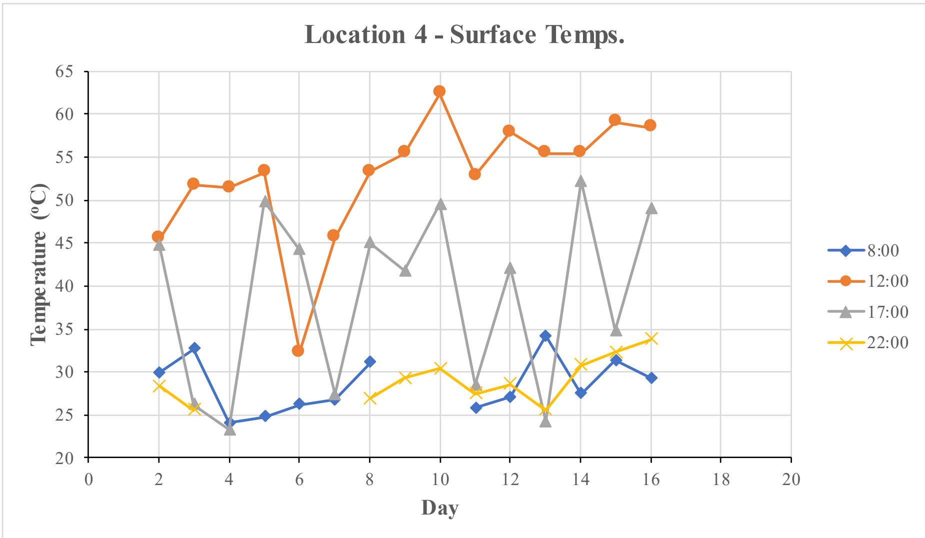
WORTH PLACE:
SURFACE TEMPERATURE

LOCATION 3 SURFACE TEMPERATURE DATA





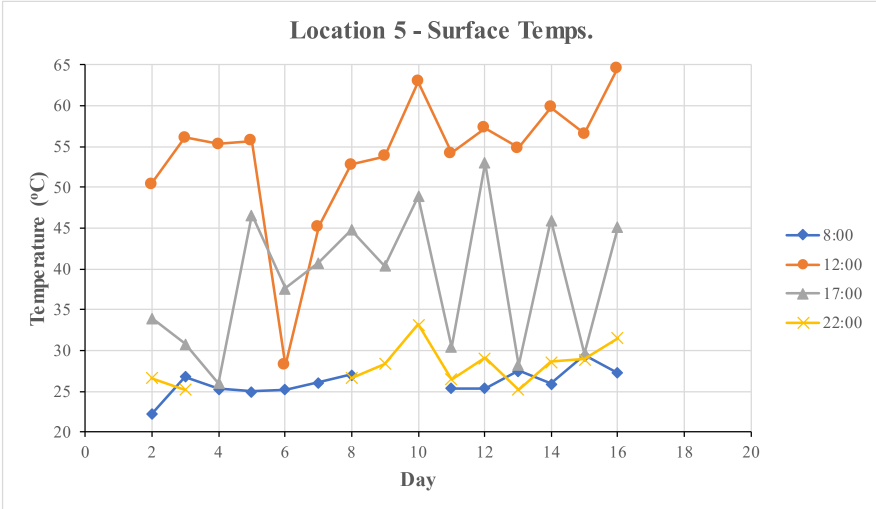
LOCATION 4 SURFACE TEMPERATURE DATA



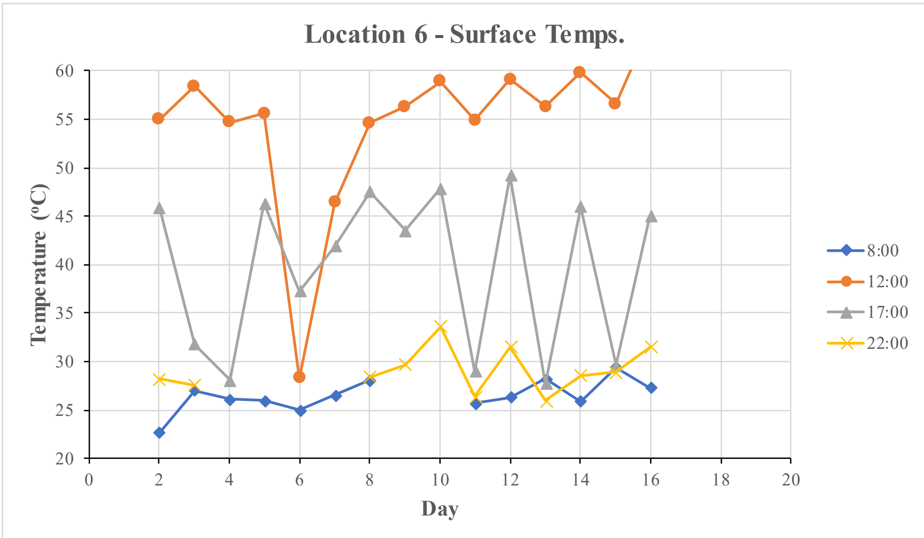
 Worth place Surface Temperature Data Location 3+ 4:
Log Location Image, Raw Data and Graph

WORTH PLACE:
SURFACE TEMPERATURE

LOCATION 5 SURFACE TEMPERATURE DATA

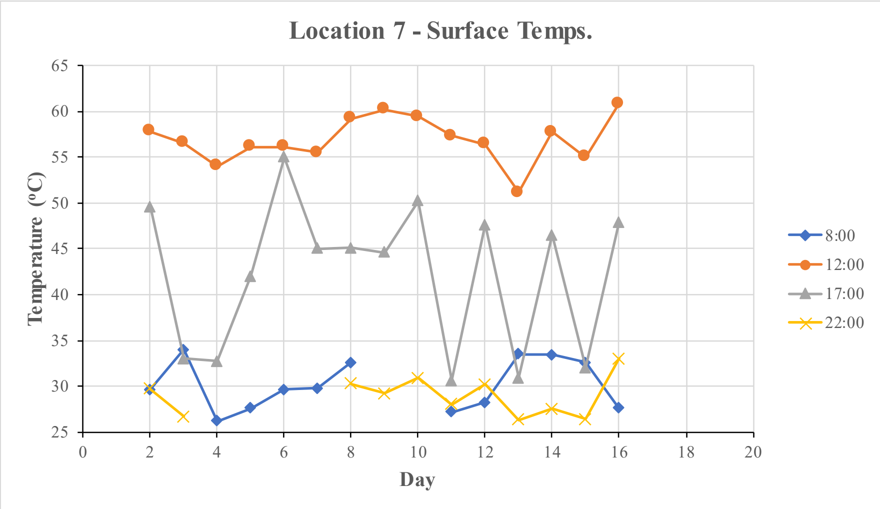


LOCATION 6 SURFACE TEMPERATURE DATA

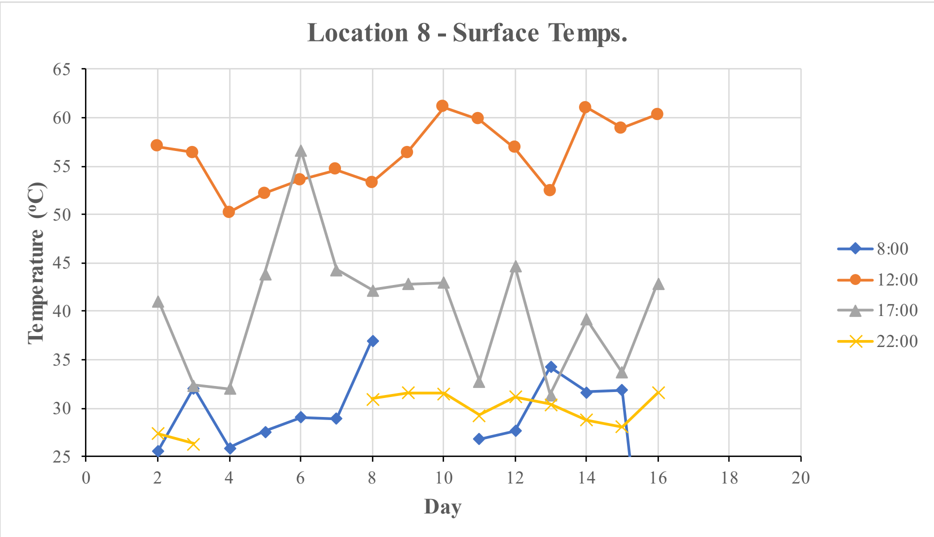


WORTH PLACE:
SURFACE TEMPERATURE

LOCATION 7 SURFACE TEMPERATURE DATA



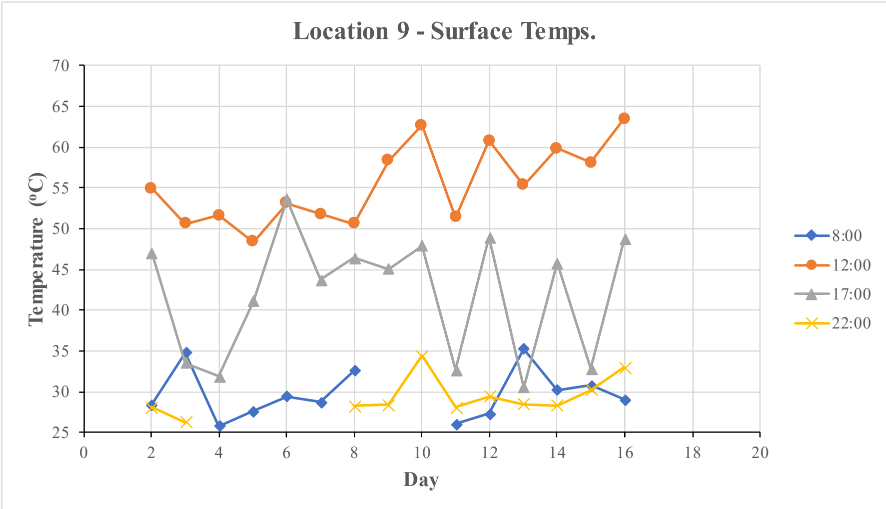
LOCATION 8 SURFACE TEMPERATURE DATA



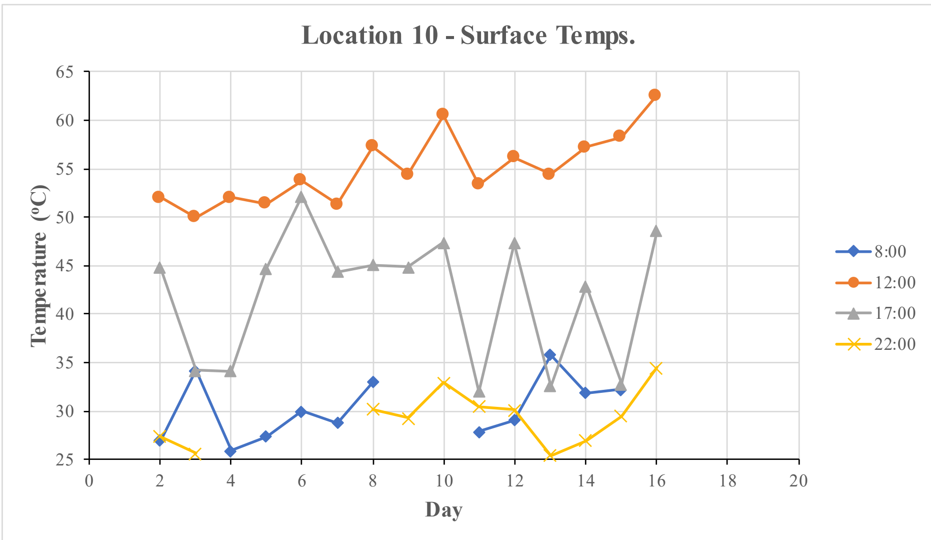
 Worth place Surface Temperature Data Location 7+ 8:
Log Location Image, Raw Data and Graph

WORTH PLACE:
SURFACE TEMPERATURE

LOCATION 9 SURFACE TEMPERATURE DATA



LOCATION 10 SURFACE TEMPERATURE DATA



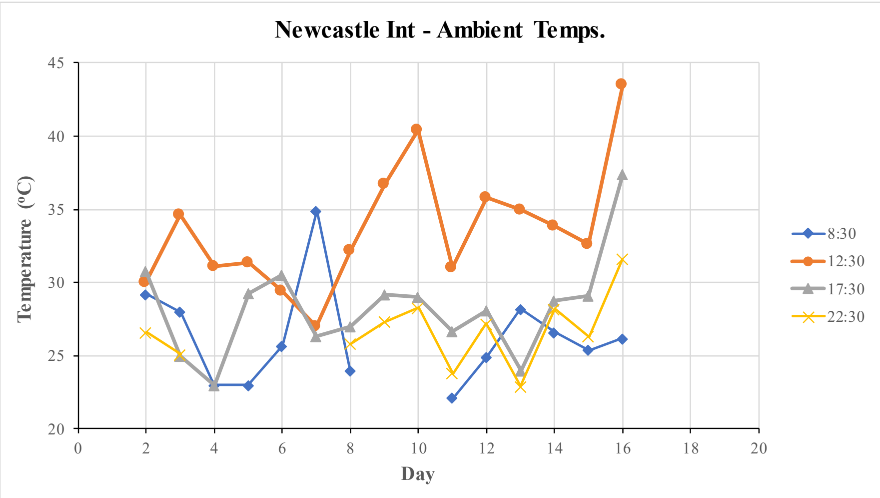
NEWCASTLE INT: SITE INFO + AMBIENT TEMPERATURE

3. NEWCASTLE INTERCHANGE

The ambient and surface temperatures of Newcastle Interchange were recorded at 10 data log locations, as depicted in the accompanying map to the RHS of the page. The panorama image below captures the urban conditions of the locations measured.

The following pages reflect the data log location conditions and the data collected, both in its raw temperature form, and visualised as a simple graph, illustrating the four measurement periods: Morning, Midday, Afternoon and After Dark. The graph on this page is the ambient or air temperatures

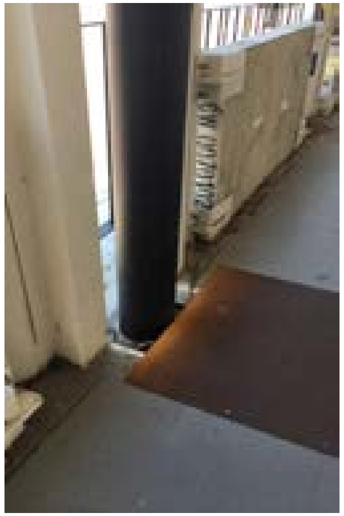
NEWCASTLE INTERCHANGE AMBIENT TEMPERATURES

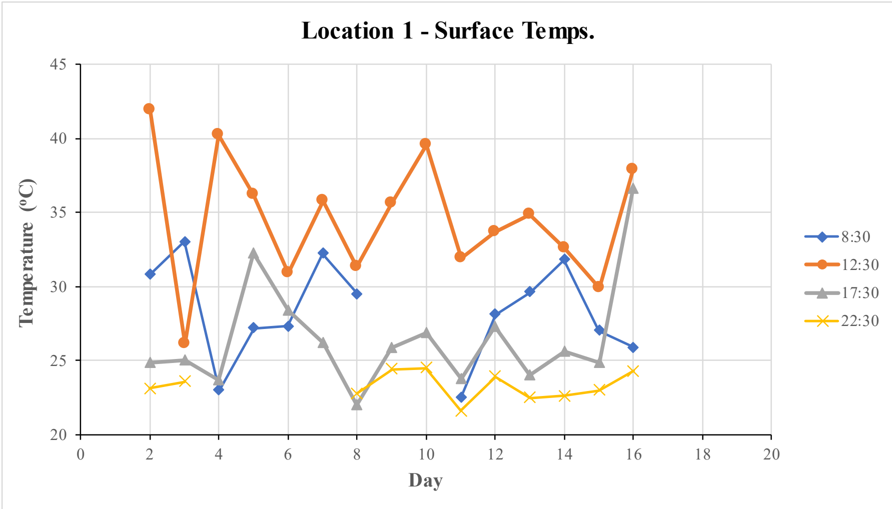


 Newcastle interchange Panorama (left); image credit Jedidiah Cranfield,
Newcastle Interchange data log locations map (right); image source NearMaps

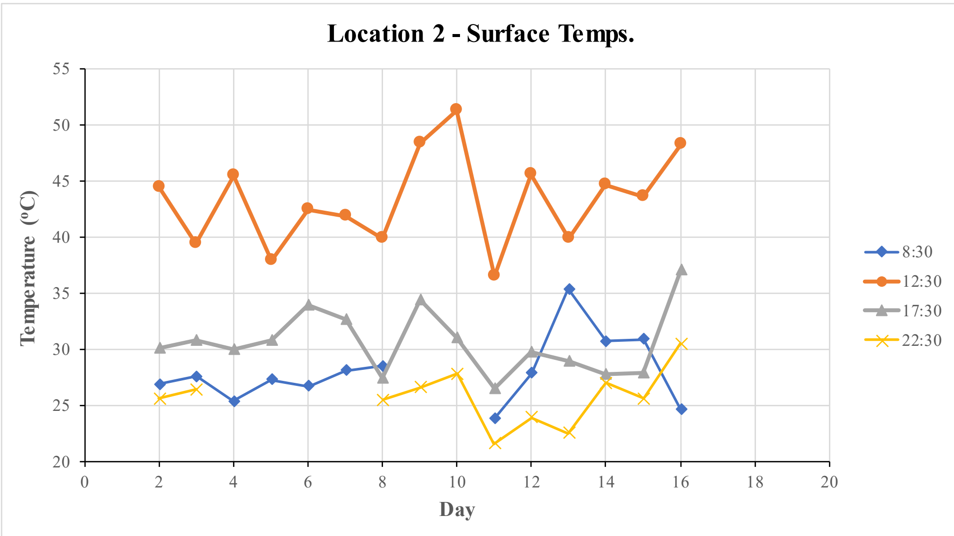
NEWCASTLE INTERCHANGE:

LOCATION 1 SURFACE TEMPERATURE DATA



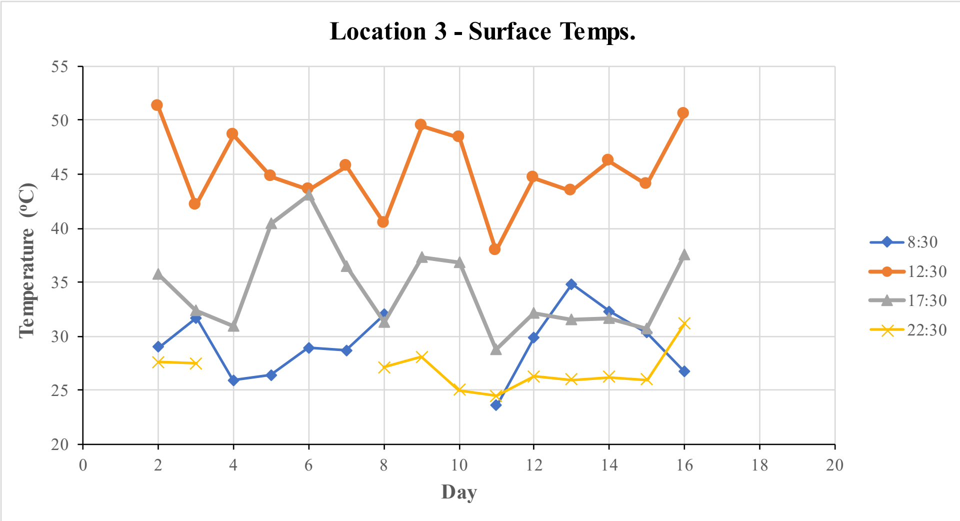


LOCATION 2 SURFACE TEMPERATURE DATA

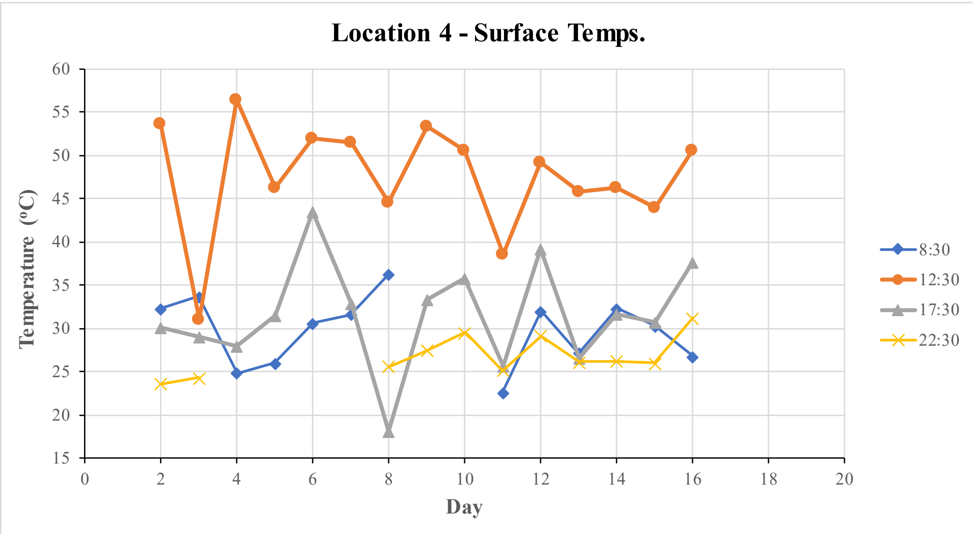


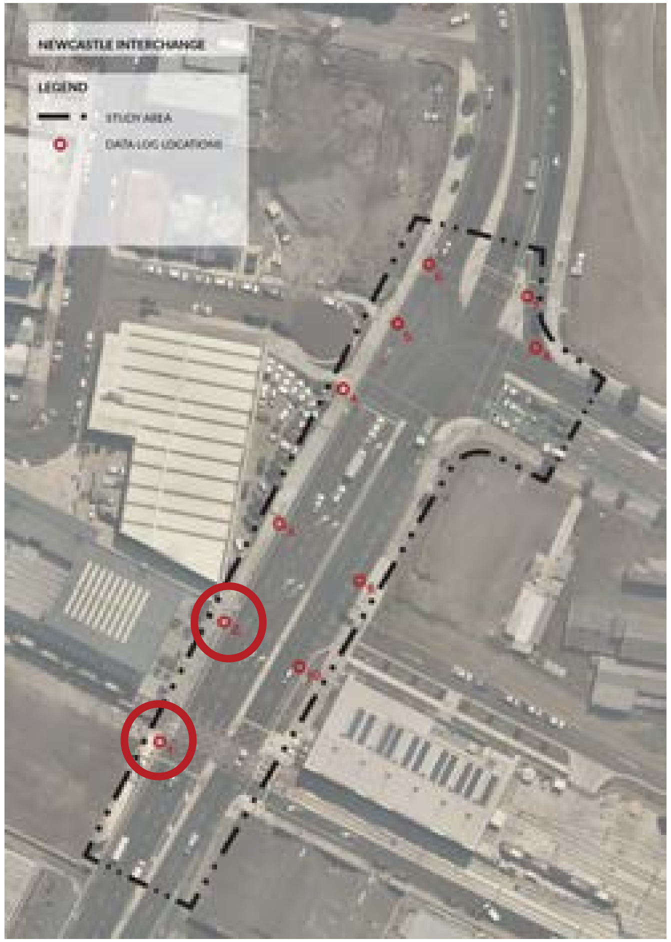
NEWCASTLE INTERCHANGE:

LOCATION 3 SURFACE TEMPERATURE DATA



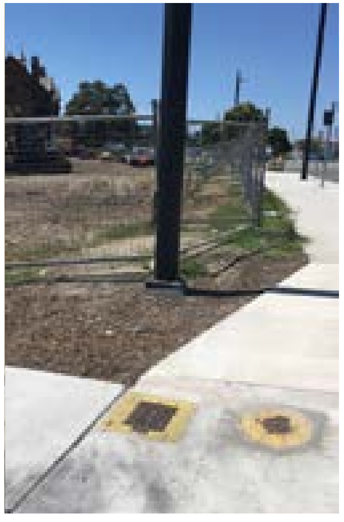
LOCATION 4 SURFACE TEMPERATURE DATA

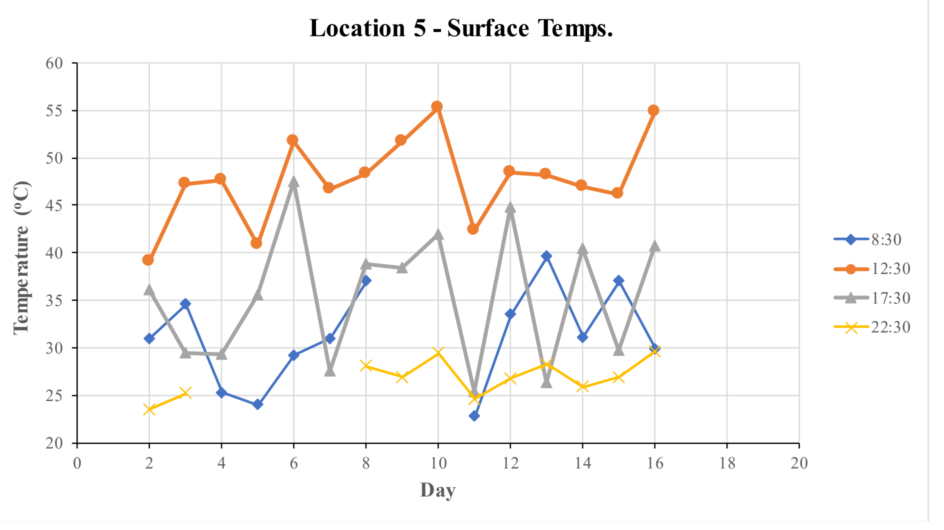




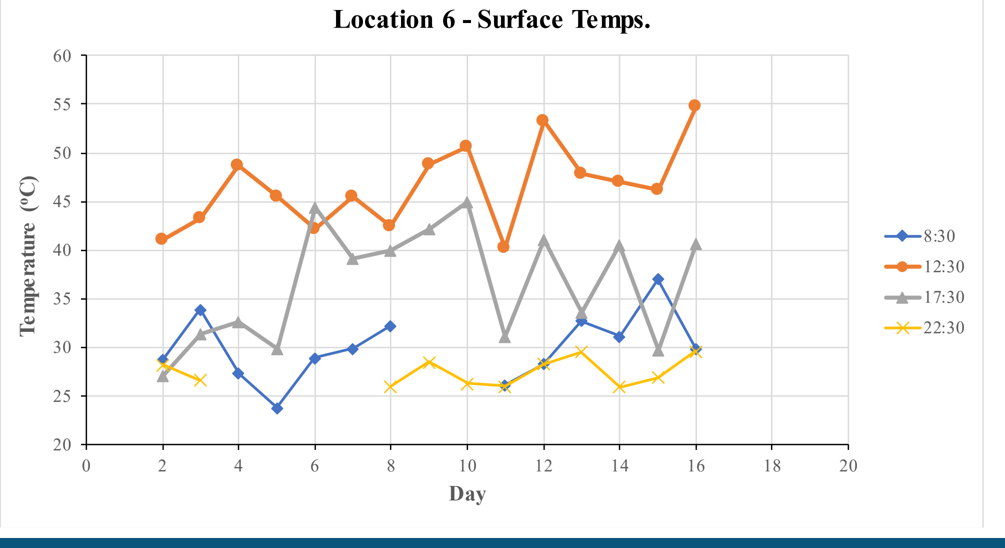
NEWCASTLE INTERCHANGE:

LOCATION 5 SURFACE TEMPERATURE DATA



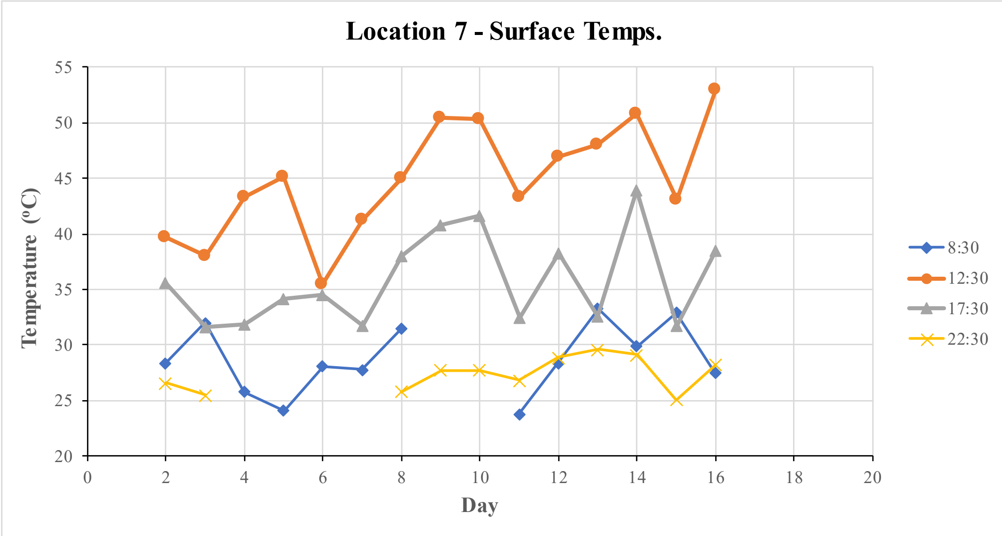


LOCATION 6 SURFACE TEMPERATURE DATA

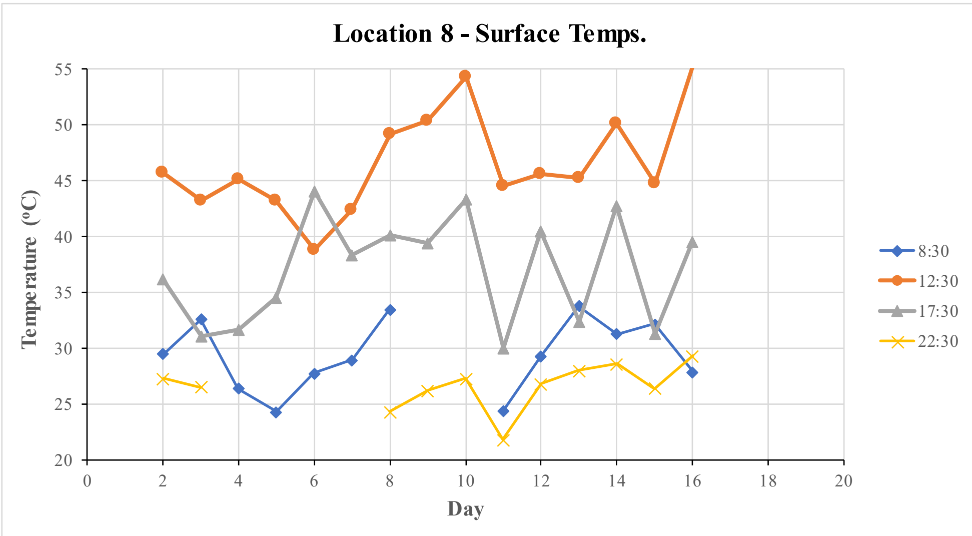


NEWCASTLE INTERCHANGE:

LOCATION 7 SURFACE TEMPERATURE DATA

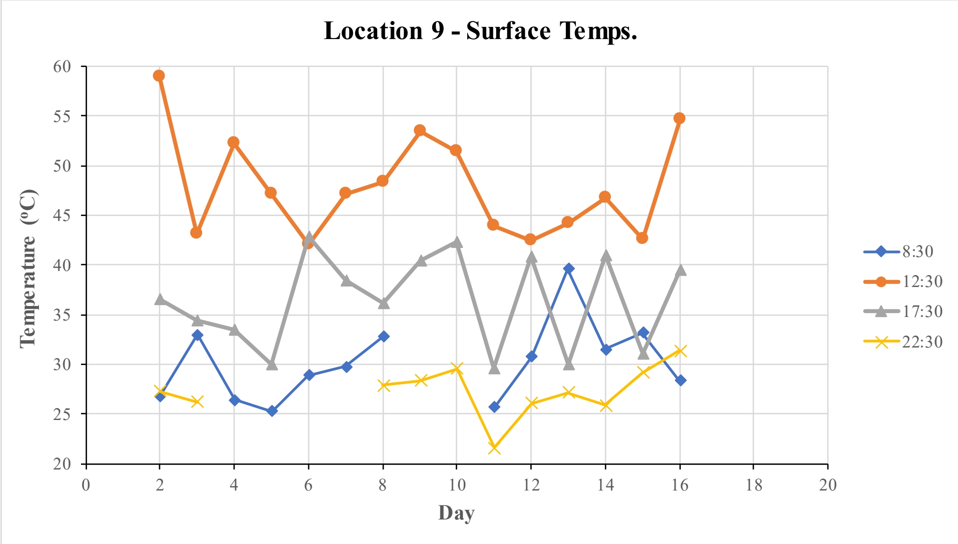


LOCATION 8 SURFACE TEMPERATURE DATA

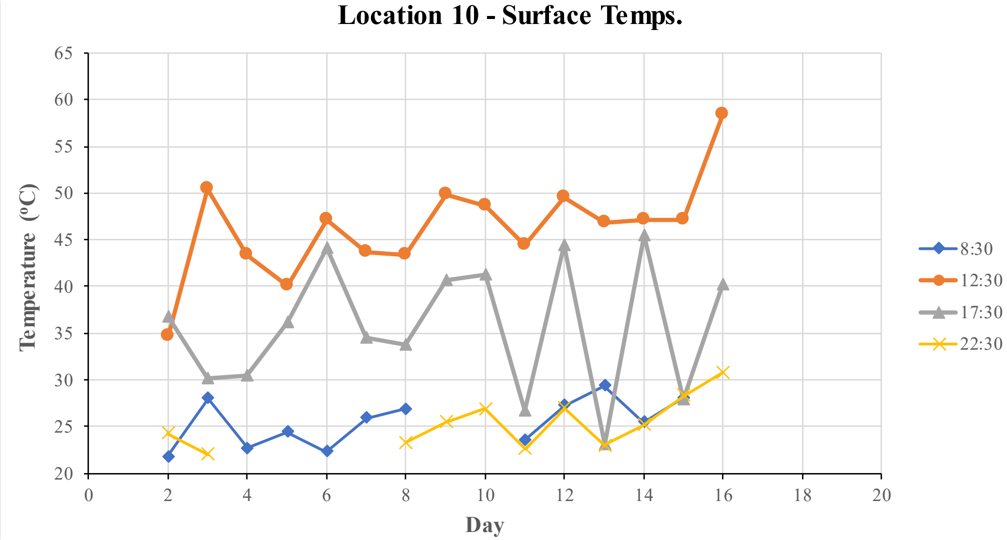


NEWCASTLE INTERCHANGE:

LOCATION 9 SURFACE TEMPERATURE DATA



LOCATION 10 SURFACE TEMPERATURE DATA



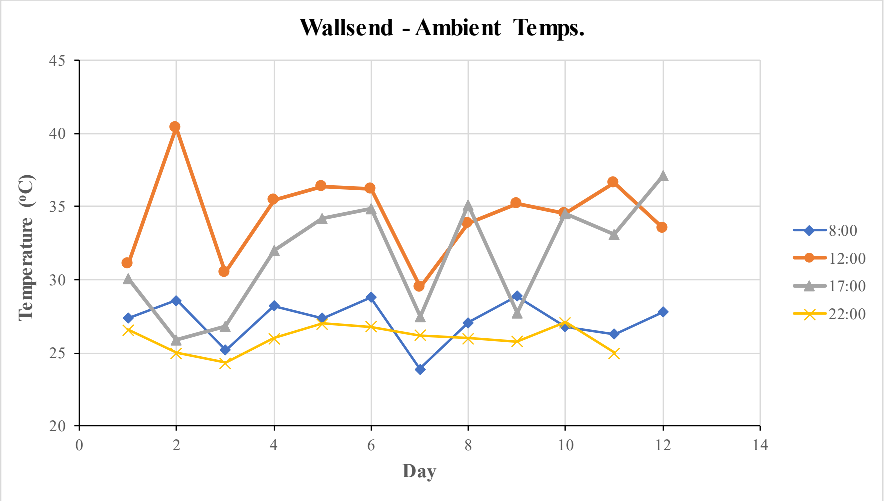
WALLSEND: SITE INFO + AMBIENT TEMPERATURE

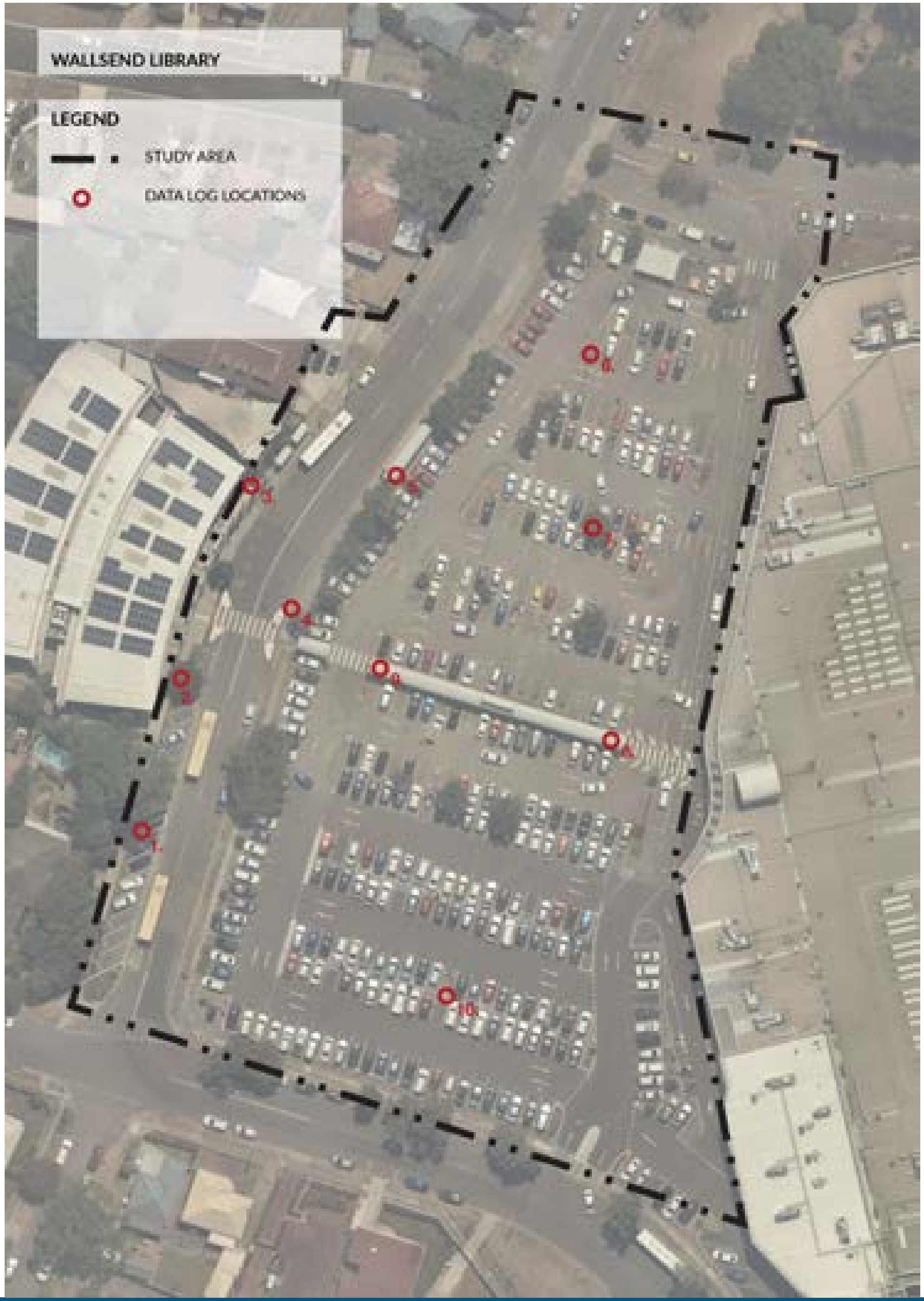
1. WALLSEND LIBRARY

The ambient and surface temperatures of the area surround Wallsend Library were recorded at 10 data log locations, as depicted in the accompanying map to the RHS of the page. The panorama image below captures the urban conditions of the locations measured.

The following pages reflect the data log location conditions and the data collected, both in its raw temperature form, and visualised as a simple graph, illustrating the four measurement periods: Morning, Midday, Afternoon and After Dark. The graph on this page is the ambient or air temperatures across the full period of data collection. The pages following are the surface temperatures.

WALLSEND LIBRARY AMBIENT TEMPERATURES

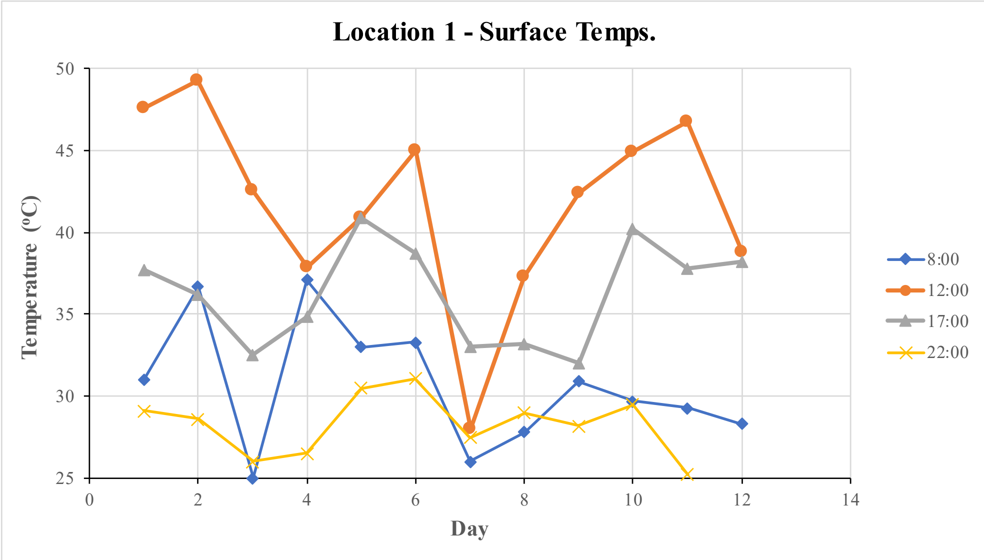




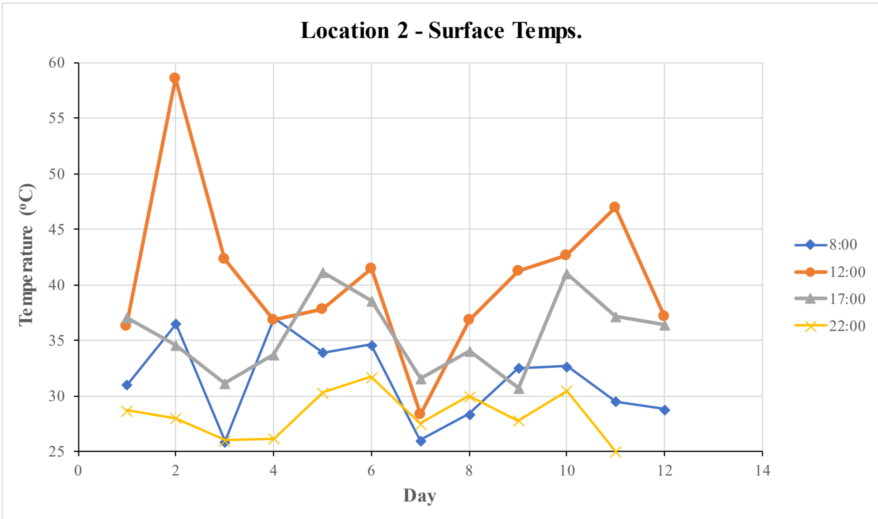
 Wallsend Library Panorama (left); image credit Jedidiah Cranfield,
Newcastle Interchange data log locations map (right); image source NearMaps

WALLSEND LIBRARY:
SURFACE TEMPERATURE

LOCATION 1 SURFACE TEMPERATURE DATA

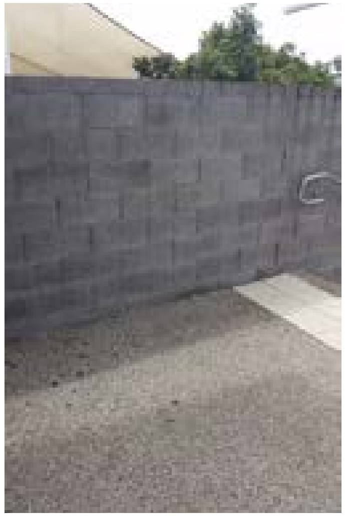


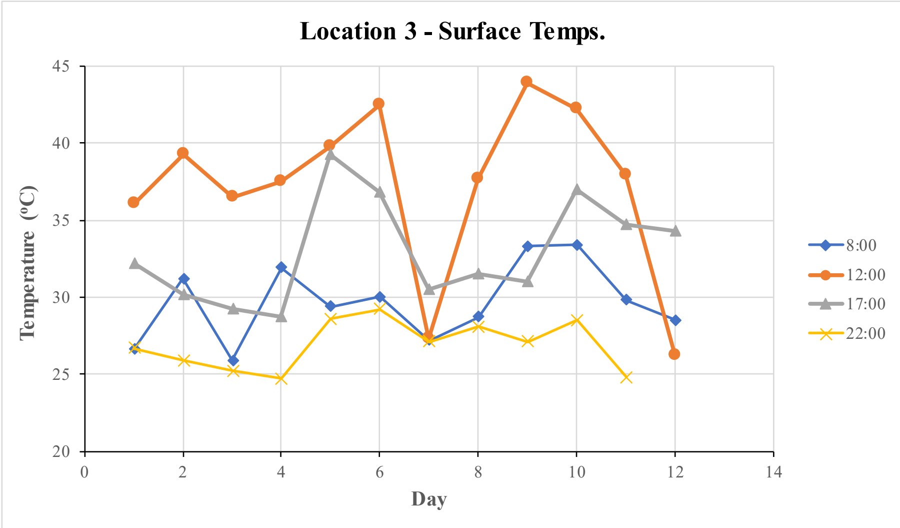
LOCATION 2 SURFACE TEMPERATURE DATA



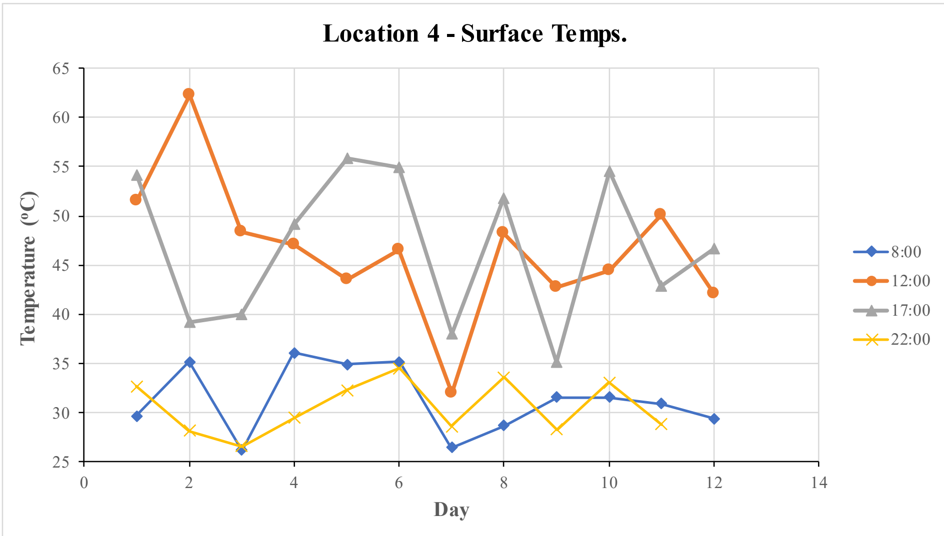
WALLSEND LIBRARY:
SURFACE TEMPERATURE

LOCATION 3 SURFACE TEMPERATURE DATA





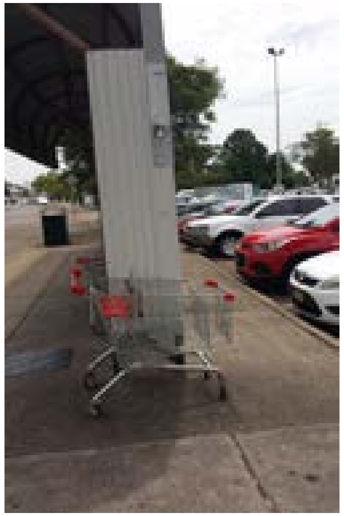
LOCATION 4 SURFACE TEMPERATURE DATA

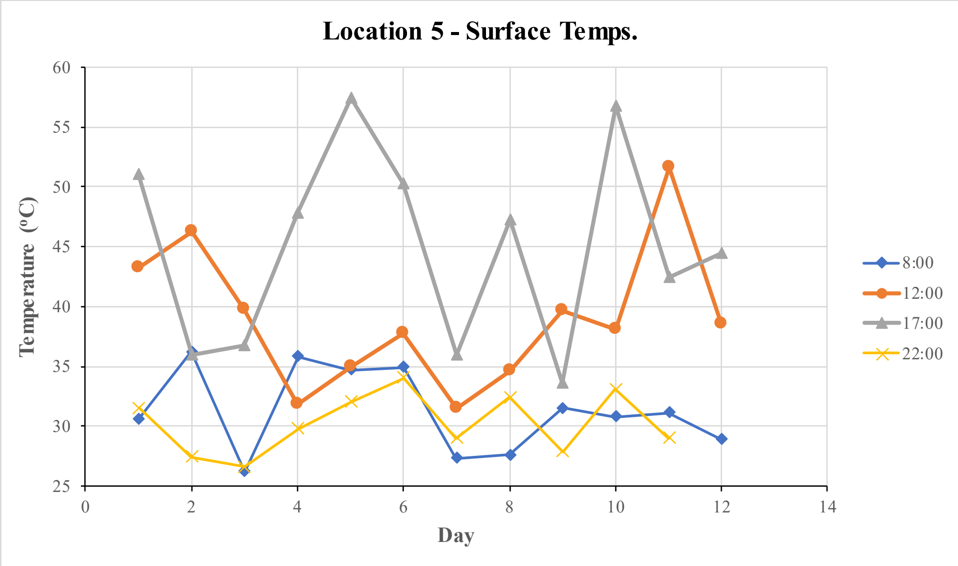


 Wallsend Library Surface Temperature Data Location 3 + 4:
Log Location Image, Raw Data and Graph

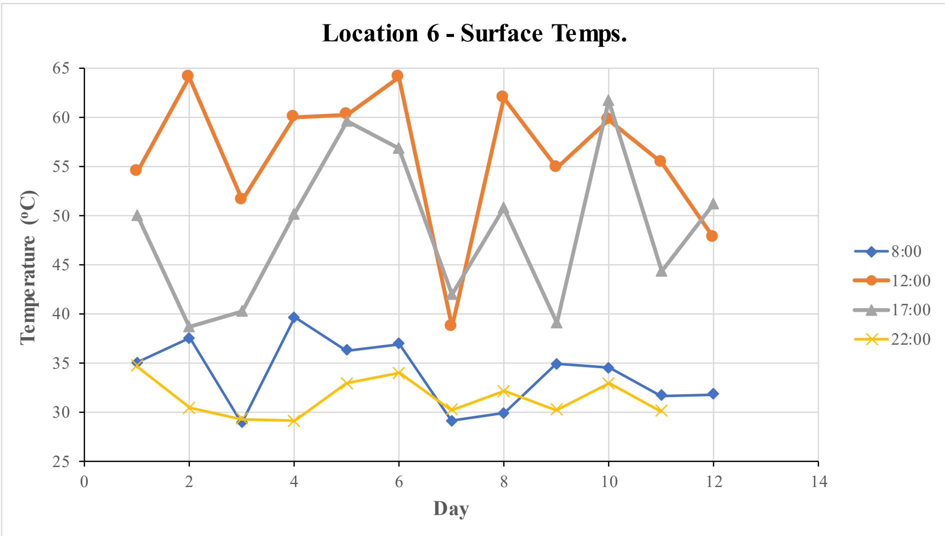
WALLSEND LIBRARY:
SURFACE TEMPERATURE

LOCATION 5 SURFACE TEMPERAT



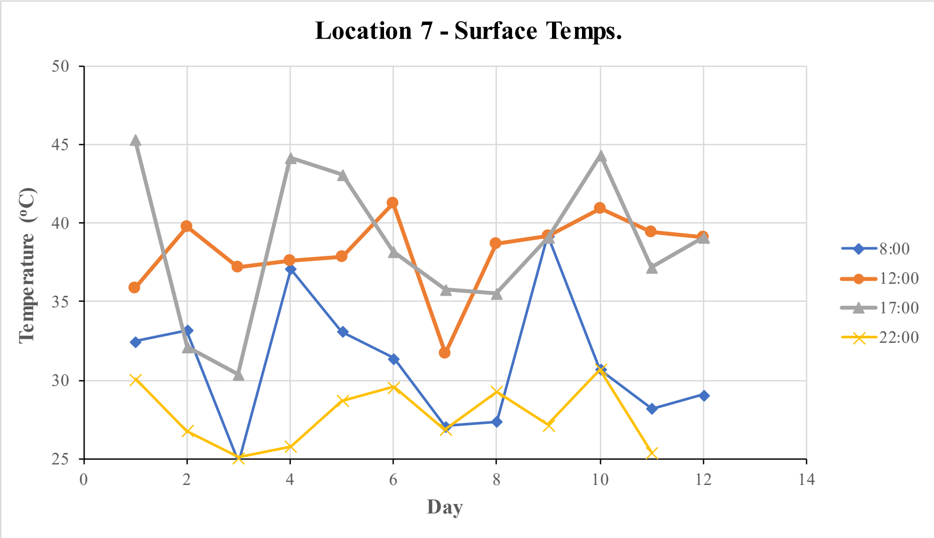


LOCATION 6 SURFACE TEMPERATURE DATA

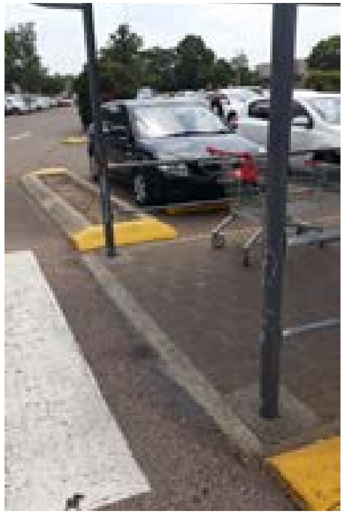


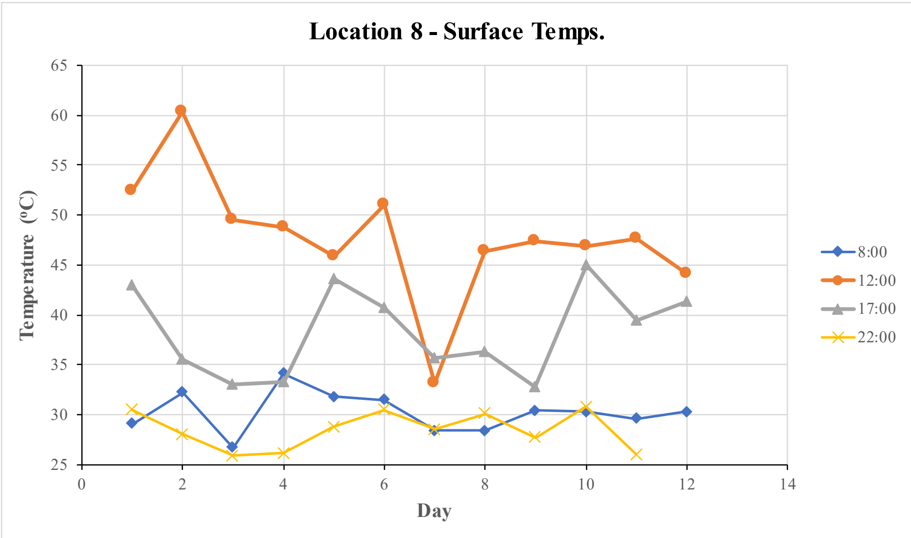
WALLSEND LIBRARY:
SURFACE TEMPERATURE

LOCATION 7 SURFACE TEMPERATURE DATA



LOCATION 8 SURFACE TEMPERATURE DATA

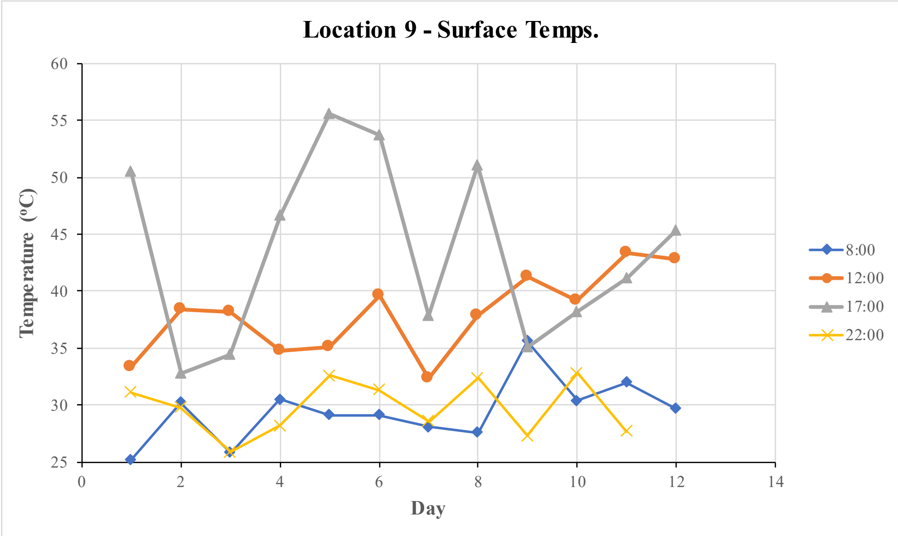




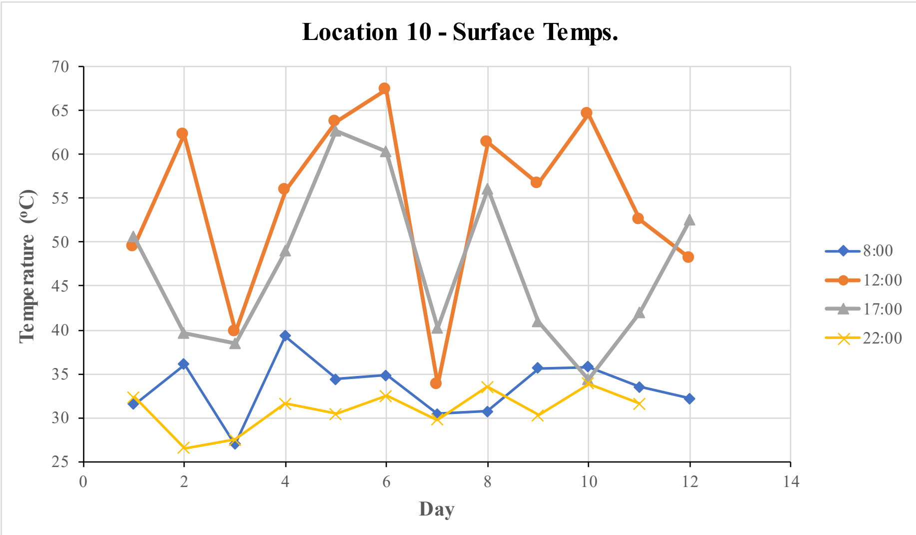
 Wallsend Library Surface Temperature Data Location 7 + 8: Log Location Image, Raw Data and Graph

WALLSEND LIBRARY:
SURFACE TEMPERATURE

LOCATION 9 SURFACE TEMPERATURE DATA



LOCATION 10 SURFACE TEMPERATURE DATA



BERESFIELD: SITE INFO + AMBIENT TEMPERATURE

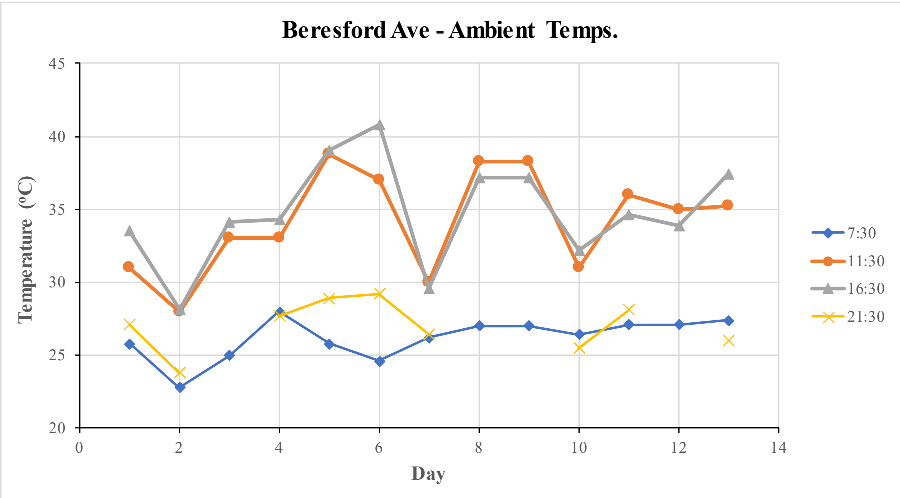
1. Beresford Avenue

The ambient and surface temperatures of the area along Beresford Ave, Beresfield were recorded at 8 data log locations, as depicted in the accompanying map to the RHS of the page.

The graphs and images over the next section reflect the data log location conditions and the data collected, both in its raw temperature form, and visualised as a simple graph, illustrating the four measurement periods: Morning, Midday, Afternoon and After Dark. The graph on this page is the ambient or air temperatures across the full period of data collection. The pages following are the surface temperatures.

The researcher who was responsible for collecting data at Beresfield payed particular attention to the materials that were present on site, and recorded the surface temperature across a broad range of materiality. This is reflected in the shifted method of visualisation that is demonstrated over the following pages.

BERESFORD AVE AMBIENT TEMPERATURES



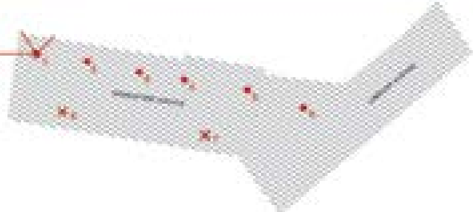
 Beresford Ave Panorama (left); image credit Jedidiah Cranfield,
Newcastle Interchange data log locations map (right); image source NearMaps

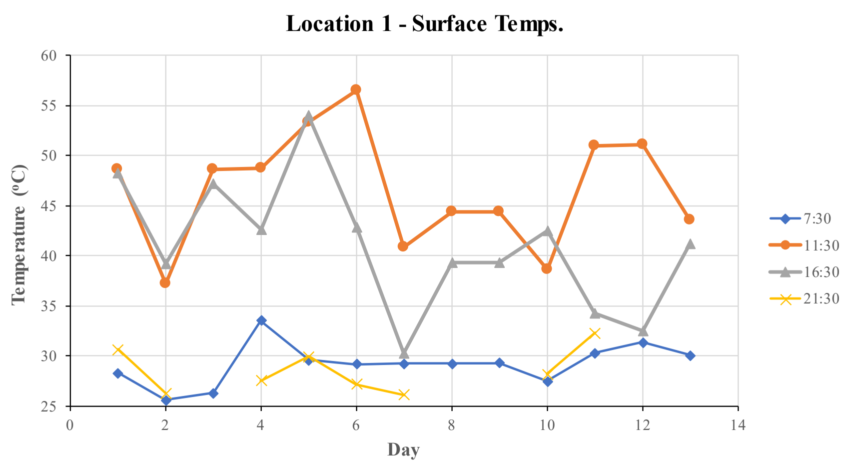
BERESFORD AVE:
DATA POINT VISUALISATIONS

Beresford Ave Panorama + data log locations diagram; image source NearMaps

BERESFORD AVE 1:
SURFACE TEMPERATURE

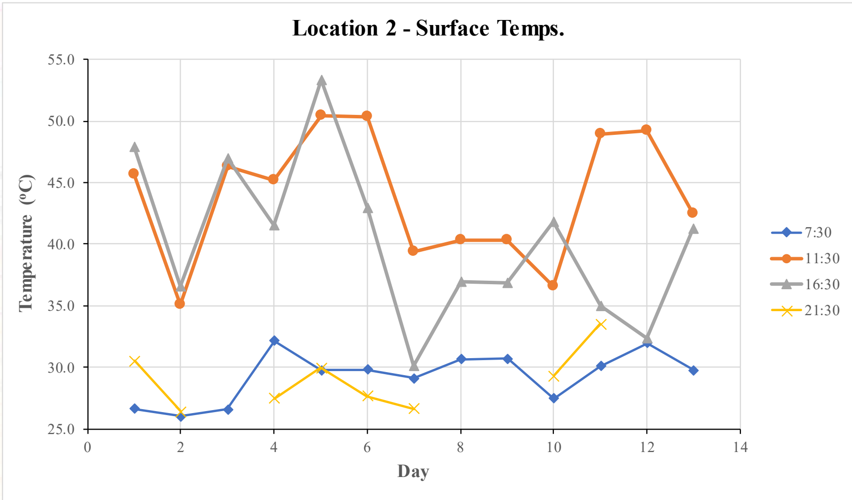
Beresfield | Location One





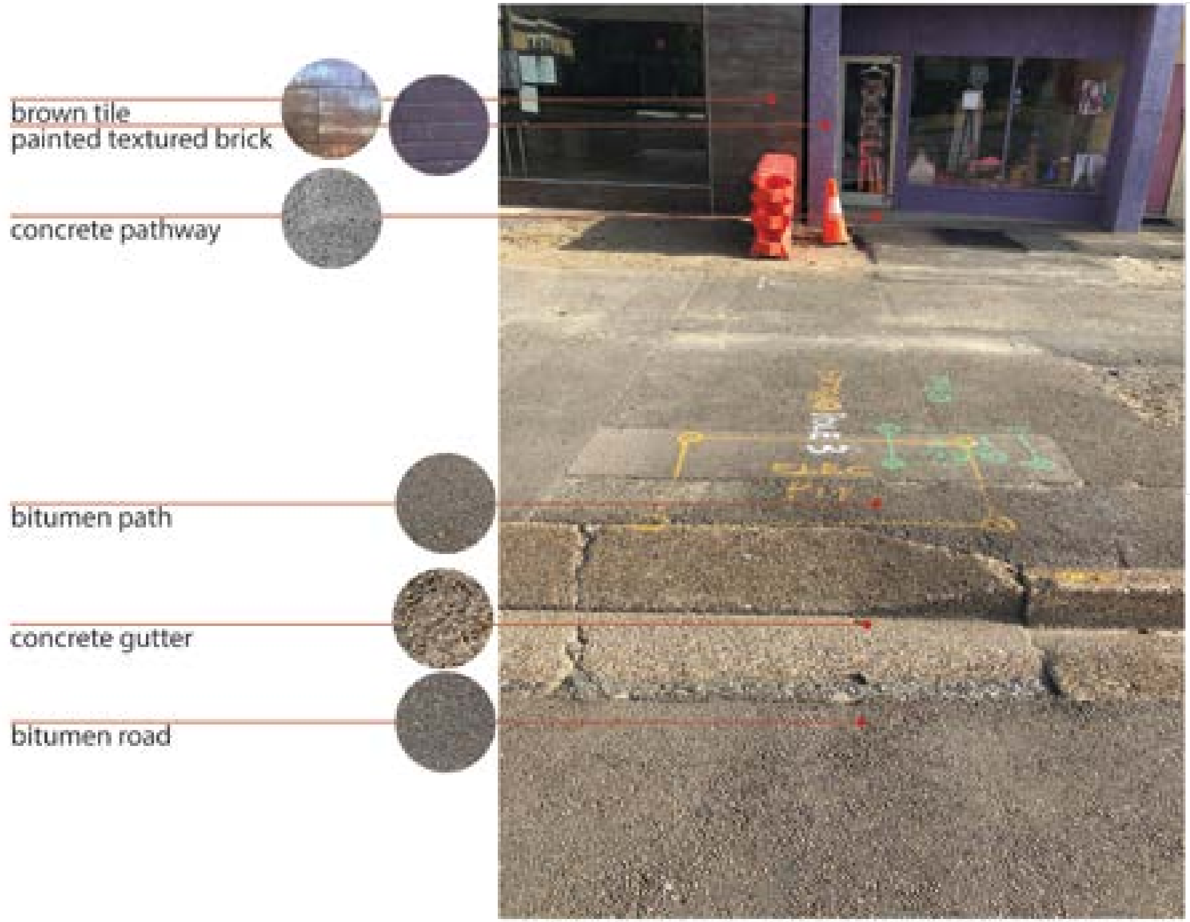
The above scatter graph is a combined average of all surface temperatures across the data log location. For individual material surface temperatures please see Rose-Charts in section 2.2 Spatialisation of Data.

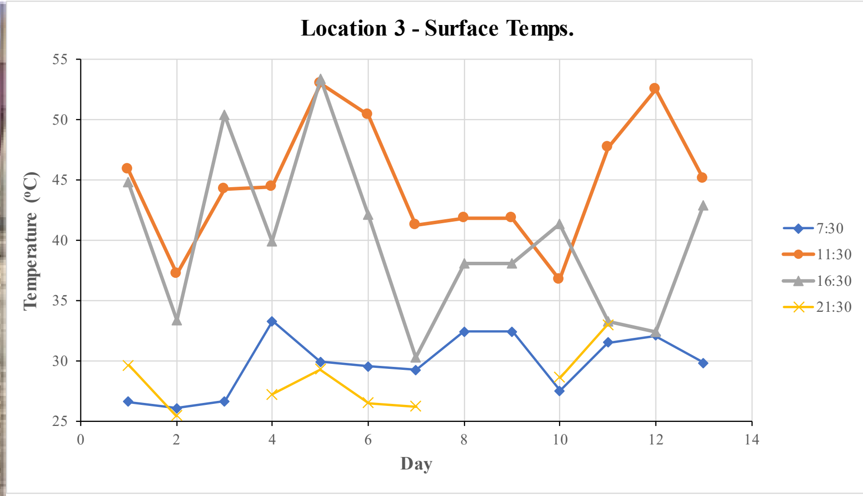
BERESFORD AVE 2:
SURFACE TEMPERATURE



The above scatter graph is a combined average of all surface temperatures across the data log location. For individual material surface temperatures please see Rose-Charts in section 2.2 Spatialisation of Data.

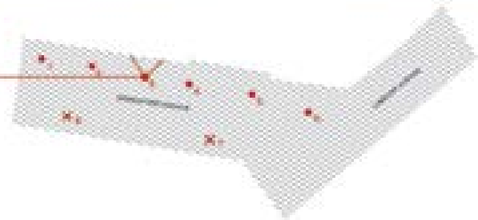
BERESFORD AVE 3:
SURFACE TEMPERATURE



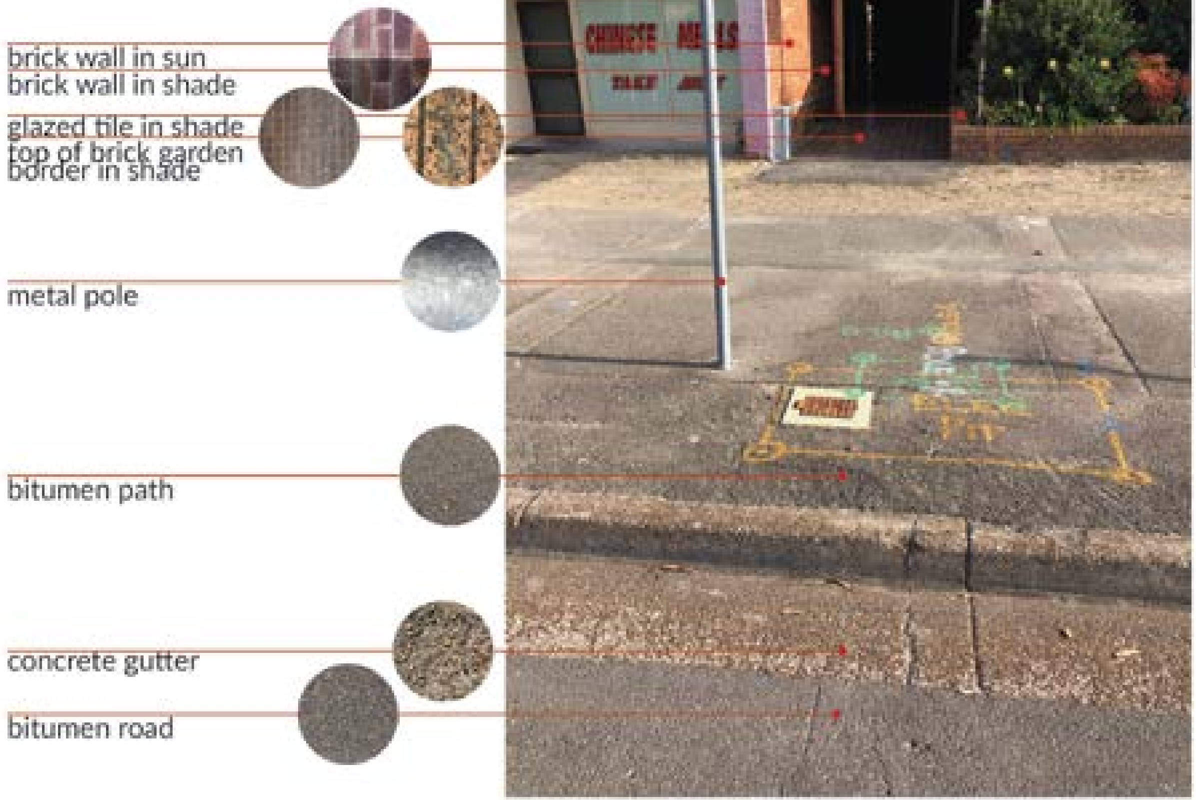


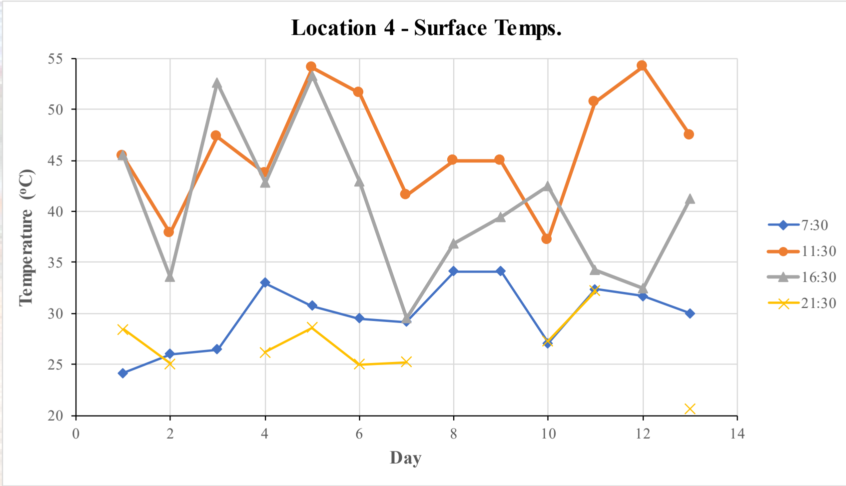
The above scatter graph is a combined average of all surface temperatures across the data log location. For individual material surface temperatures please see Rose-Charts in section 2.2 Spatialisation of Data.

Beresfield | Location Three



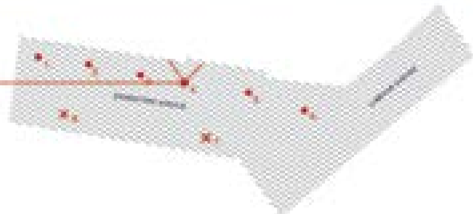
BERESFORD AVE 4:
SURFACE TEMPERATURE



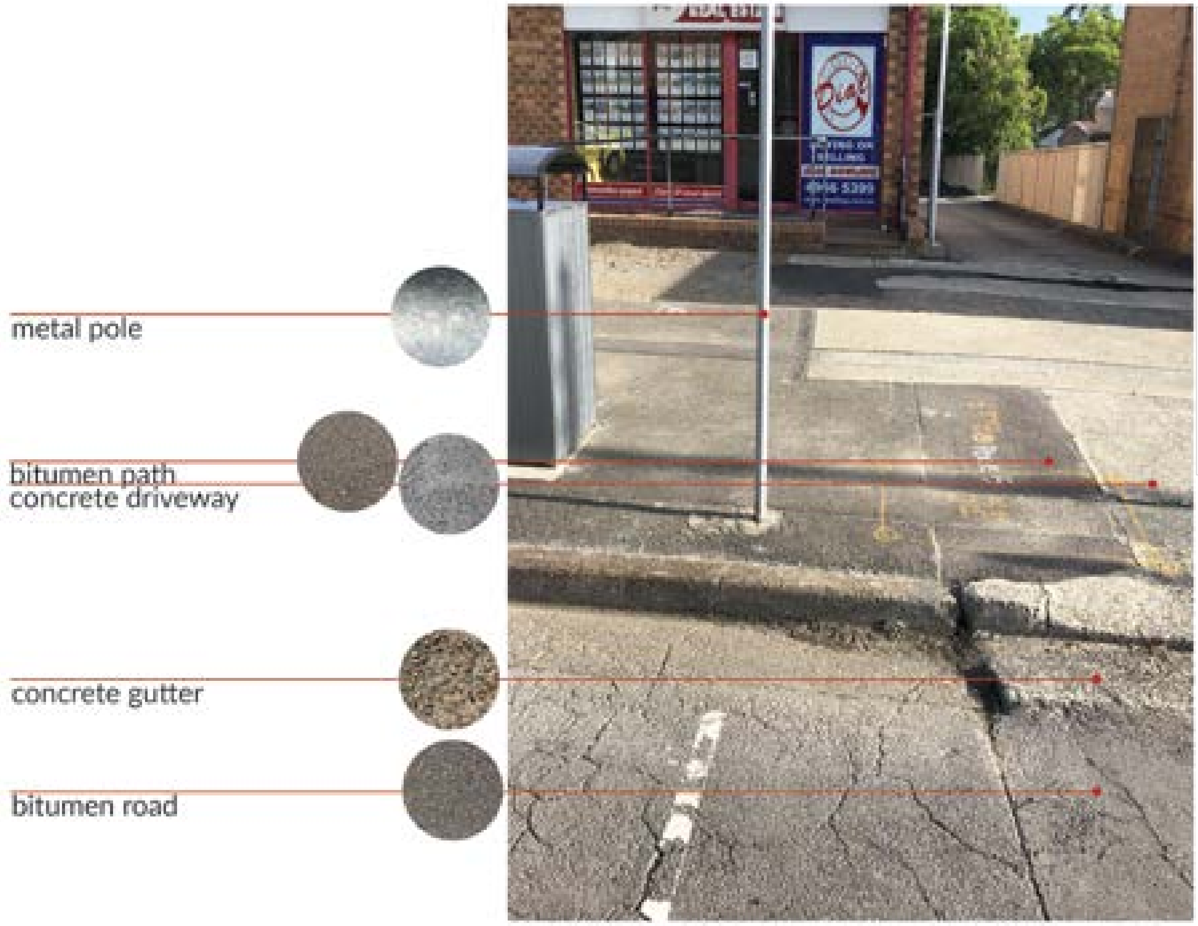


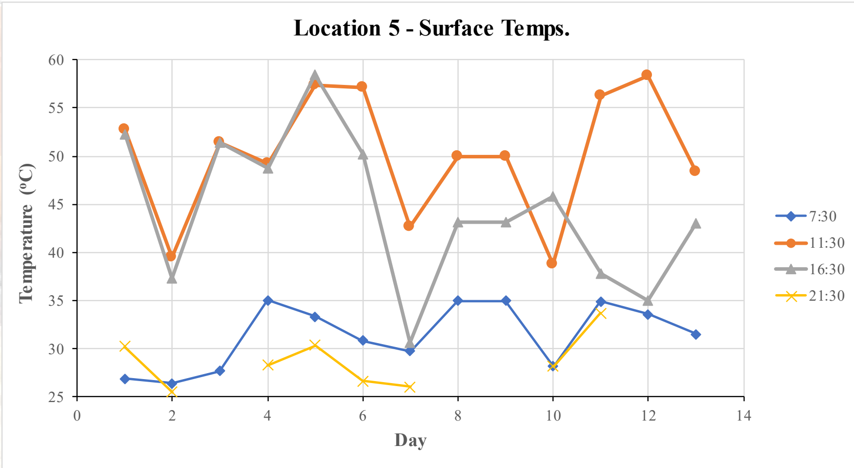
The above scatter graph is a combined average of all surface temperatures across the data log location. For individual material surface temperatures please see Rose-Charts in section 2.2 Spatialisation of Data.

Beresfield | Location Four



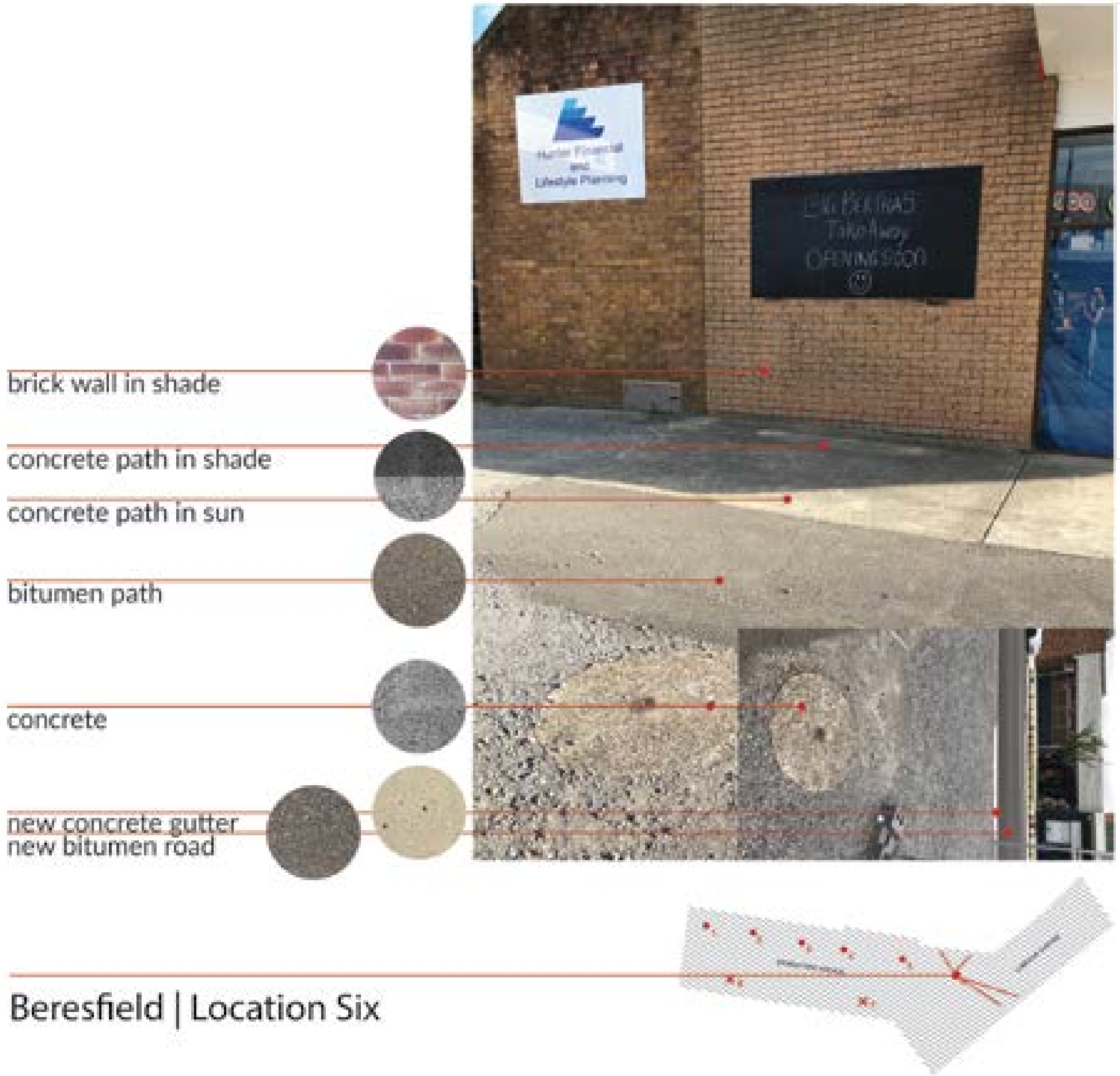
BERESFORD AVE 5:
SURFACE TEMPERATURE

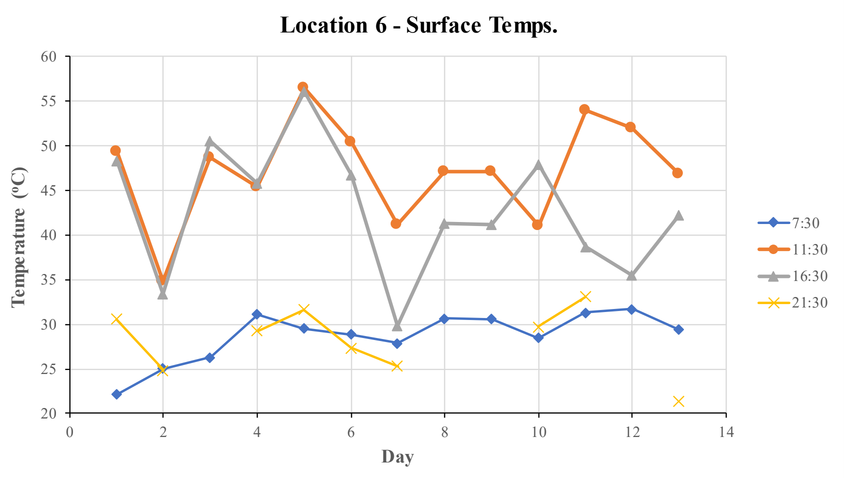




The above scatter graph is a combined average of all surface temperatures across the data log location. For individual material surface temperatures please see Rose-Charts in section 2.2 Spatialisation of Data.

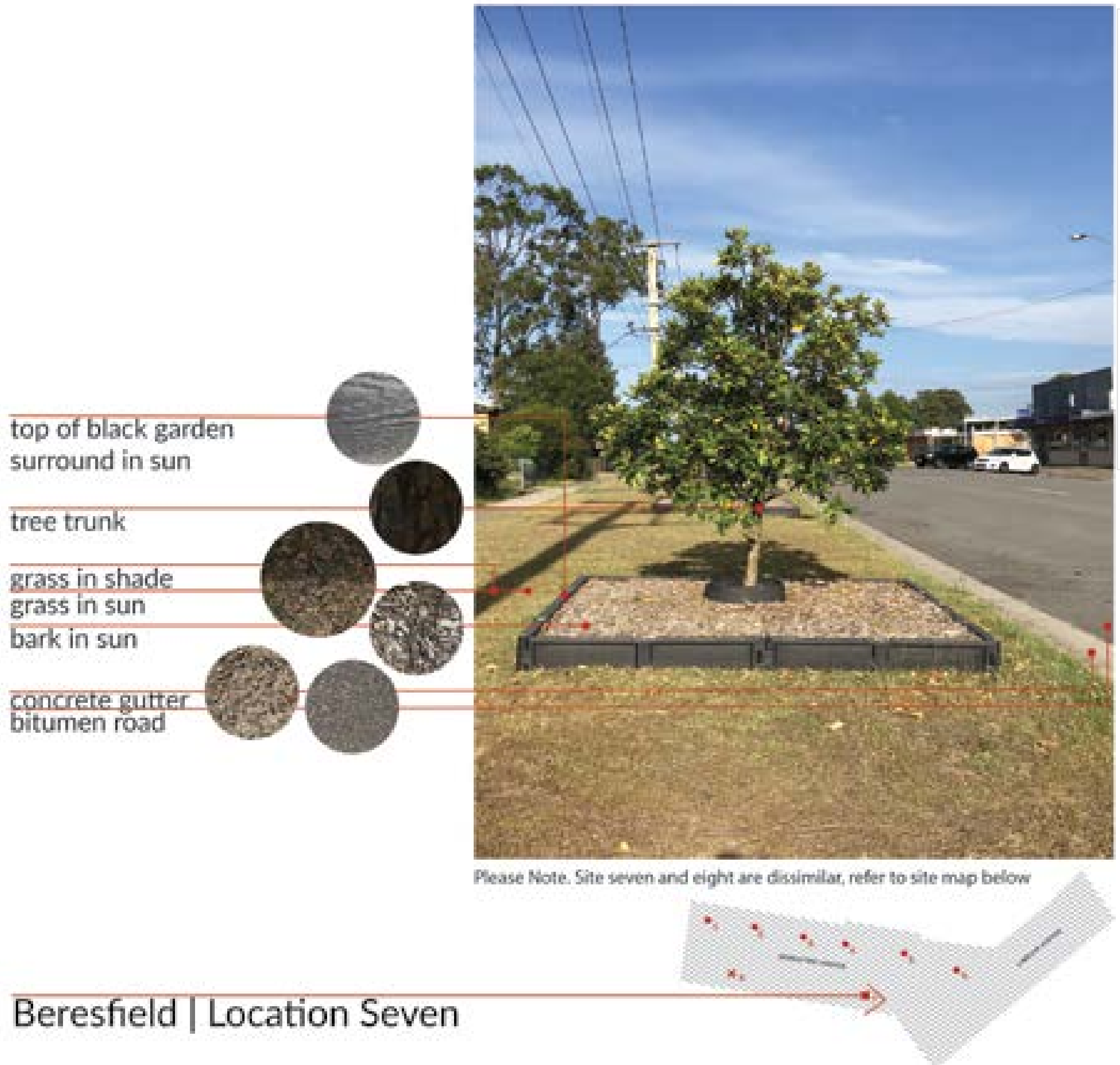
BERESFORD AVE 6:
SURFACE TEMPERATURE

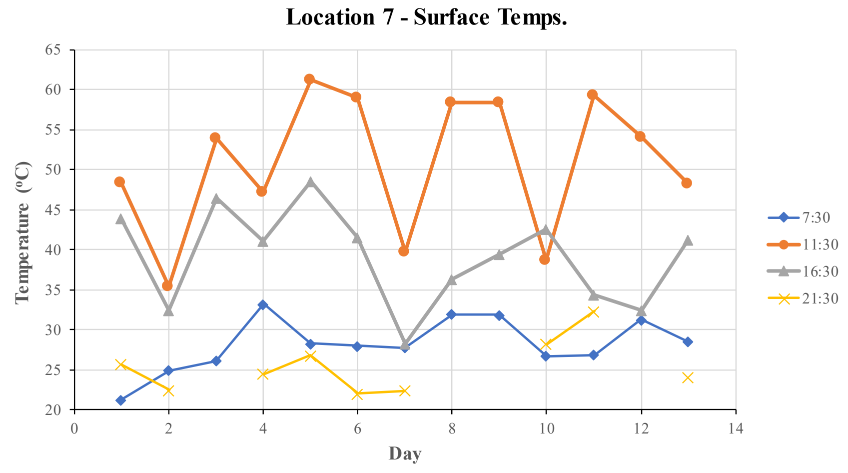




The above scatter graph is a combined average of all surface temperatures across the data log location. For individual material surface temperatures please see Rose-Charts in section 2.2 Spatialisation of Data.

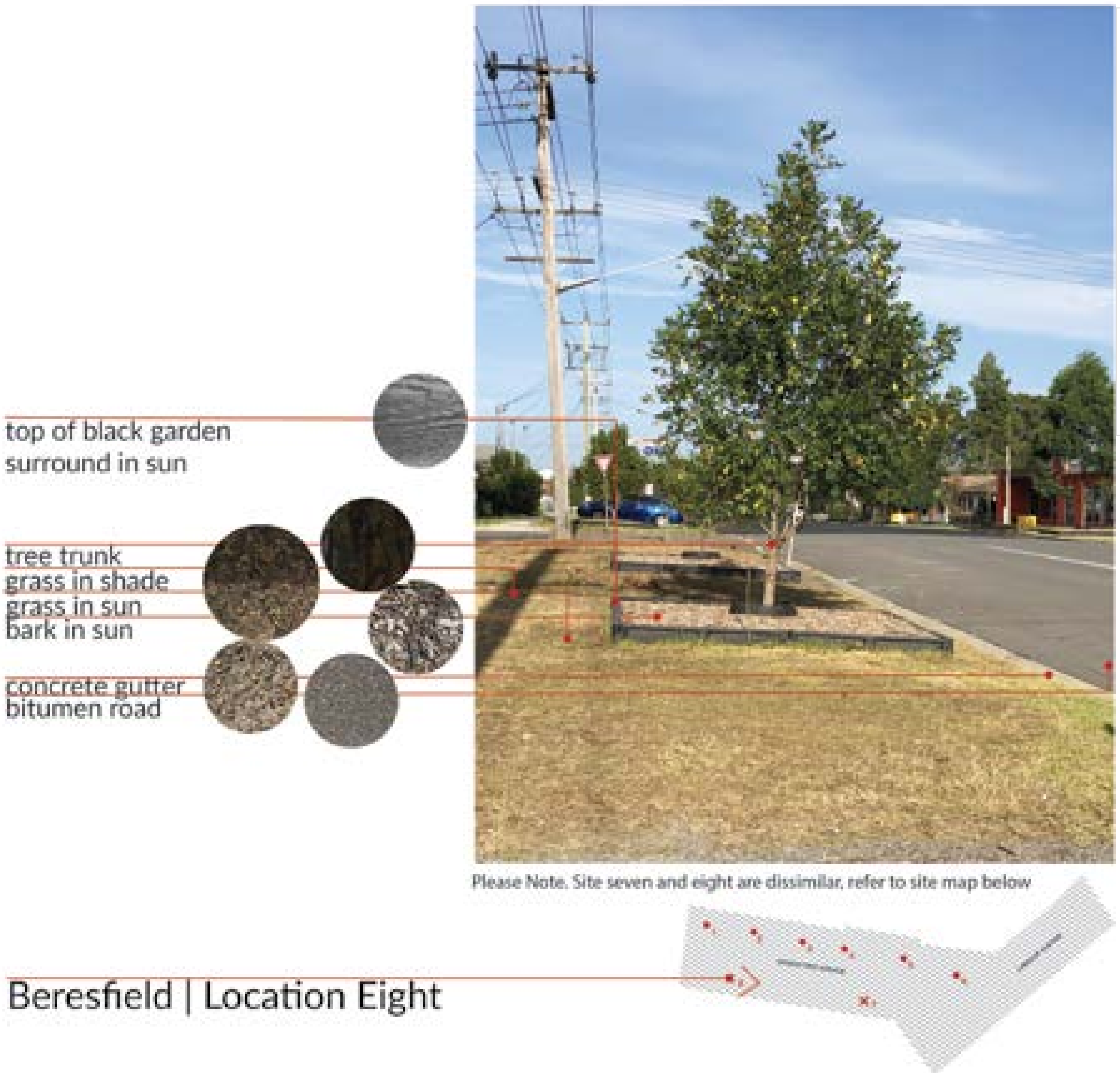
BERESFORD AVE 7:
SURFACE TEMPERATURE

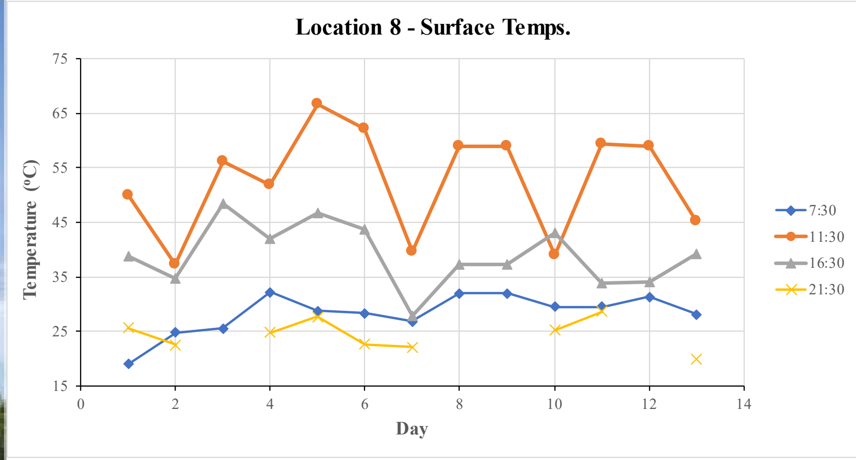




The above scatter graph is a combined average of all surface temperatures across the data log location. For individual material surface temperatures please see Rose-Charts in section 2.2 Spatialisation of Data.

BERESFORD AVE 8:
SURFACE TEMPERATURE





The above scatter graph is a combined average of all surface temperatures across the data log location. For individual material surface temperatures please see Rose-Charts in section 2.2 Spatialisation of Data.

SUMMARY

VISUALISATION: SCATTER GRAPHS - SUMMARY

The visualisation of temperatures across the 12 - 16 day periods through scatter graphs begins to break the data collected down from numbers in an excel spreadsheet to a visual barometer of thermal experiences. However, the legibility of the graphs need adjacent imagery of data point locations in a site plan and a data point photograph. Additionally, inclusion of the comparable ambient temperatures at times during the day was difficult and confusing.

Though it is important to note that through the process of visualising the data, indications of peak temperature periods within the days cycle become apparent, as does the impact of materiality on the surface temperatures collected. These graphs provide an easily replicated and reasonably accessible data set that could be linked to live data feeds from the smart pole network in the future.

These scatter graphs as a separate set of data do not facilitate easy comparison between the sites, and as such the data was further explored through the lens of materials present across all sites.

By compiling the average temperatures and assigning each log locater a predominant material the research was layered with an extra set of simple graphs that explored the ratio between air and surface temperatures present. The following section is a result of the aggregated surface temperatures and the ambient temperatures.

Visualisation: MATERIALS 2.1.1

MATERIAL VISUALISATIONS:
PIE CHART

The presentation of the temperature data through graph visuals and corresponding maps are somewhat limiting when seeking an understanding of the radiant heat properties of the individual materials surveyed. The following visualization emphasize this aspect of the data, and explore alternate methods of conveying temperature results.

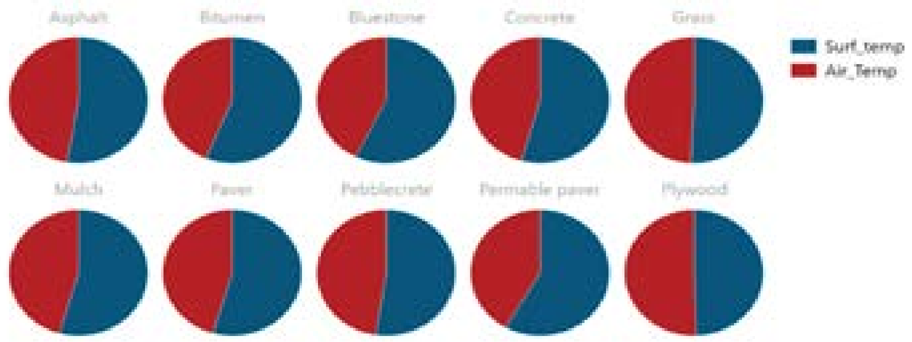
The pie charts are extracting the surface and ambient temperatures from each of the five sites and grouping them by material. These animated graphs provide insight into which materials retain and re-radiate heat at a greater rate than others.

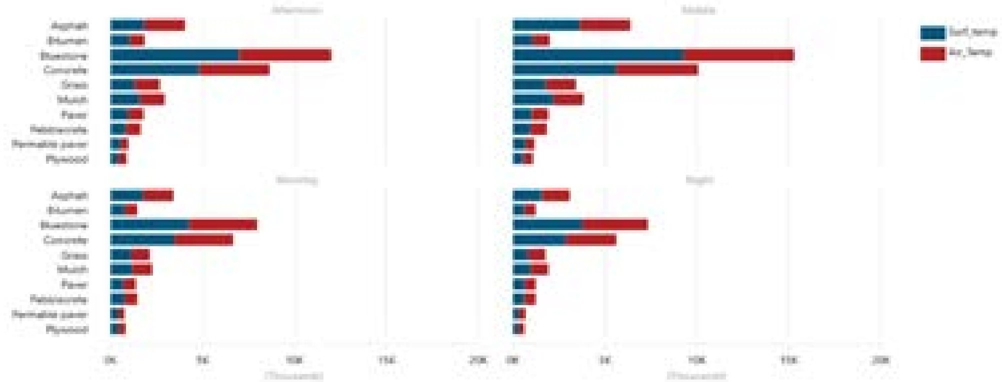
The chart demonstrates the differing ratio of air vs surface temperature apparent in each material present across the 5 sites. Through the use of an interactive excel sheet, this visualisation method draws on the graph data to illustrate the difference between the air and surface temperatures.

This chart may also be made interactive - with the ability to select and highlight a specific materials performance during the day.

The following statistics are some of the particularly notable temperature ratios for materials that emerge from this pie chart:

1. **Asphalt:**
   Average temperature ratio: MIDDAY **1.38**, EVENING **1.04**
2. **Bitumen:**
   Average temperature ratio: MIDDAY **1.37**, EVENING **1.14**
4. **Bluestone:**
   Average temperature ratio: MIDDAY **1.56**, EVENING **1.08**
3. **Grass:**
   Average temperature ratio: MIDDAY **1.11**, EVENING **0.88**





Pie Chart indicating ratio between average Ambient and Surface Temperatures,
Figures compiled across all five sites.

SUMMARY OF CONCLUSIONS:
VISUALISATIONS OF DATA

SUMMARY OF CONCLUSIONS

The process of collecting the temperature data onsite and then visualising it using accessible means, was illuminating for the research team. In particular, the difficulties of conveying “hard numbers” and relative comfort as well as material performance comparisons. So while the graphs were effective at locating what the data was and where it was collected, the adjacent images still failed to capture the spatial properties of the sites and the hot spots. Additionally, the pie charts which take average temperature data across the five sites for dominate materials and compare them with ambient temperatures at four times per day, attempted to demonstrate the performance of materials in situ. They also sought to highlight which materials hold heat longer into the day after ambient temperatures cool. Similarly, these pie charts and graphs proved to be confusing, when disaggregated from the sites themselves. In the next section of the report, the team sought to address issues and spatialise the data.

Spatialisation of Data 2.2

INTRODUCTION

This section explores different ways of spatialising temperature data collected during the study. The primary method that was utilised was the photography of the streetscape to visually locate temperature readings in physical space. Data is "spatialised" by highlighting areas and providing a summarised breakdown of recorded temperatures. This is supported by Rose-charts that visually link measured temperatures to the materials at each site and indicate when temperatures exceed safe limits.

Once the temperature data was visualised, through graphs, pie charts, graphs and bar charts it became evident that the research team needed to explore the results/outcomes through alternativevisual means. The previous sets of information are accessible to certain user groups, however they are not legible to many wider user groups including those who are the most vulnerable to the impacts and dangers of UHIE.

In order to communicate the effects of UHIE, emphasize the potential dangers of extreme heat exposure, and suggest alternative measures or better options in materiality; the research team felt it was necessary to connect the data better with the spaces that generated it. Additionally, these techniques were developed to foster a greater specificity of place (recognisable through panoramas) and offer comparative data at a micro scale. The research team anticipated a greater level of engagement with the information, if spatial techniques are utilised, allowing the user to place themselves within the scenario depicted.

Our research team focused on two guiding questions when spatialising the data:

1. How do we indicate dangerous temperature spatially?
2. What are the key messages that inform this data?

The following pages provide a series of Rose-charts and stills from interactive Panoramas to spatially deomonstrate the varying surface and air temperatures across locations, data log points and materials throughout the day. This is the full set of each locations' spatialisation imagery. Through a layering of images, text, icons or symbols, and colour these spatialisations seek to clarify and engage potential users in the data collected - providing a visual sense of the site conditions that allows the user to place themselves in the scenario and interact/engage with the information actively.

These materials have been reduced in size and interactivity has been altered to align with the report format. If NCC requires the full scale interactive versions of the panoramas or the rose-charts these must be obtained from UoN separately.

METHODOLOGY

ICONS

The use of icons or symbols simplifies and unifies information. By utilising a visual language tool, we are then able to separate, delineate and itemise our results. The development of the selected icons linked directly into the materials present across the five sites, as we began to group them in relation to their physical presence. The six categories within the icons or symbol sets also link directly to the Kit of Parts and Mitigation Techniques, and the categories of approach that they represent. The icons can directly link into our kit of parts/mitigation matrix, allowing for simple, easy to read images. The facing page lists the icons that we utilised in our images.

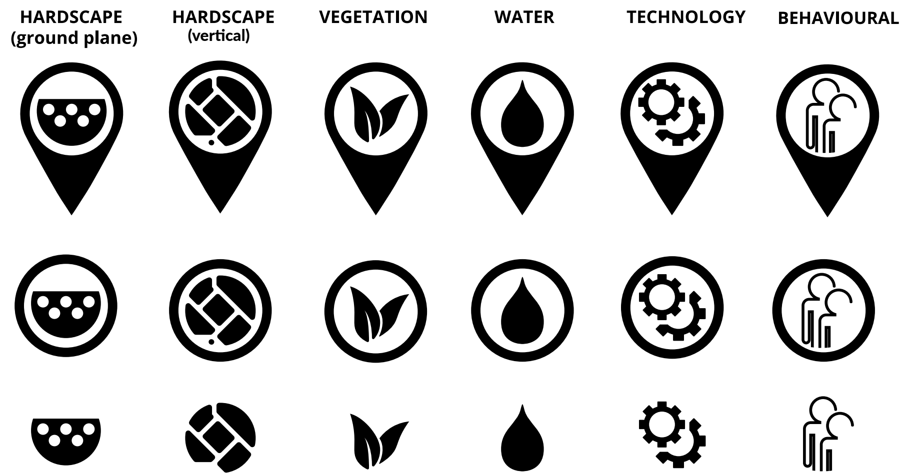
ROSECHART

The Rose-Chart is a multi- faceted and complex spatialisation technique. Layering all the available information, we've tried to provide a clear, effective and powerful tool which allows a comparison of the material palette, differing temperatures, and data collection locations. The rose-charts sought to provide a comprehensive picture or synthesis of the data recorded and over-laid with site condition information. See page 65 for further explanation and demonstration.

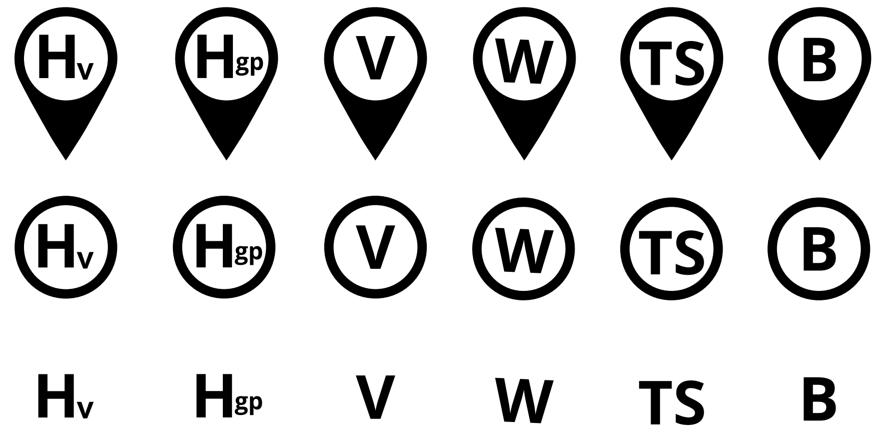
PANORAMAS

Panormas are an effective locating tool as an alternative to plans or maps. Using photography taken from the eye level of a pedestrian, data can be communicated through the experience of standing on site. Through interactive PD's we are able to move through the sites in a dynamic, engaging and concise manner. Layering of the icons keeps the image clean, and clear. See page 66 for further explanation and demonstration.

ICONS: PRIMARY

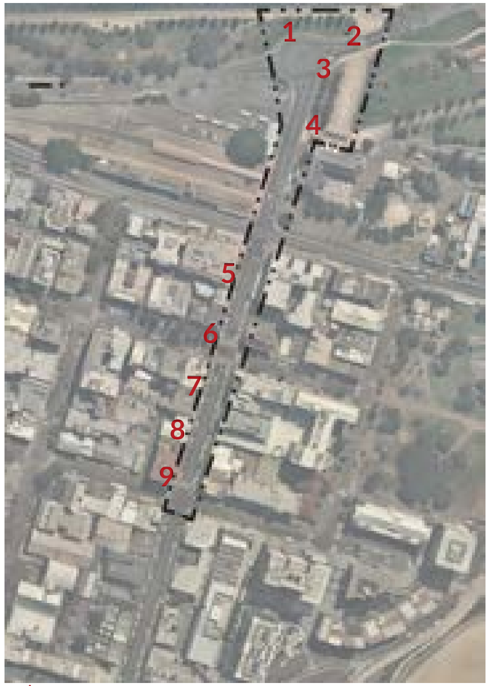


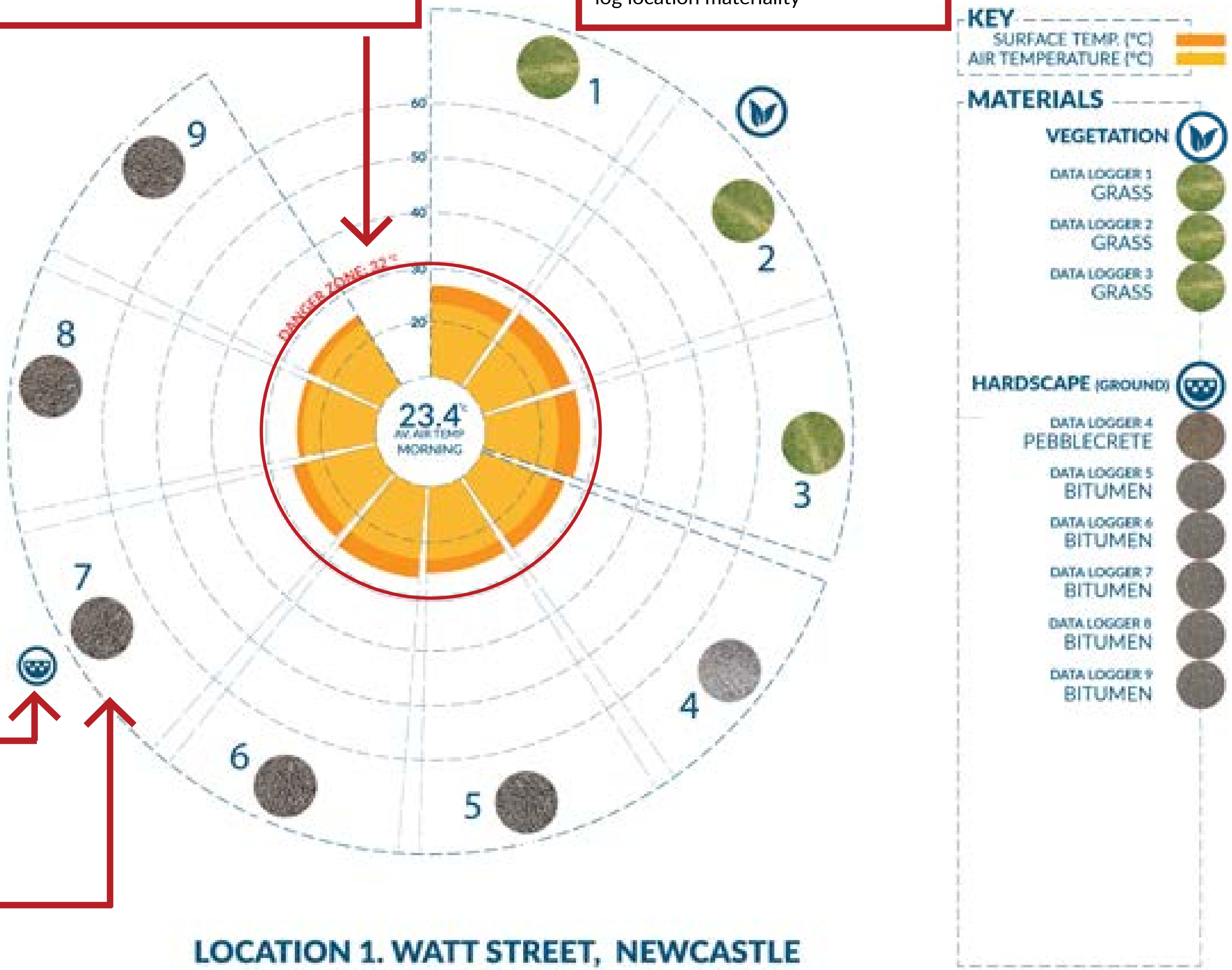
ICONS: SECONDARY



Danger Zone Threshold
Sustained exposure to temperatures above 32 degress celsius pose a health risk to vuneralble user groups

Rose-Chart Key
Indicating which colours represent surface/ambient temperature, explaining icons and detailing data log location materiality





Site Location Plan Key

Icon describing site conditions

Data Log Point + Material Segement
Highlighting data log location and which material is providing the surface temperature reading

PANORAMA: WATT ST PANORAMA EXAMPLE

Focus Area
Highlighting the specific data log location the written data is refering to. Icons is used to identify the material providing the surface temperature.

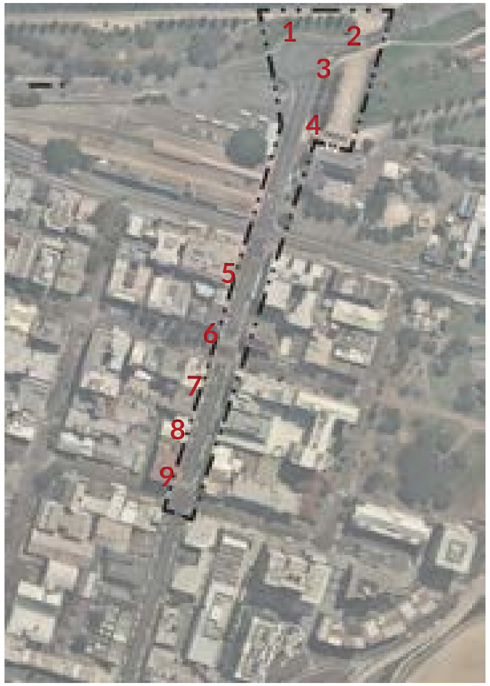
Data Log Location
Material identified through icons - Hardscape (Ground Plane)

Data Log Location Results
Detailing average, minimum and maximum temperature results for that location from: Morning, Midday, Afternoon and Afterdark.

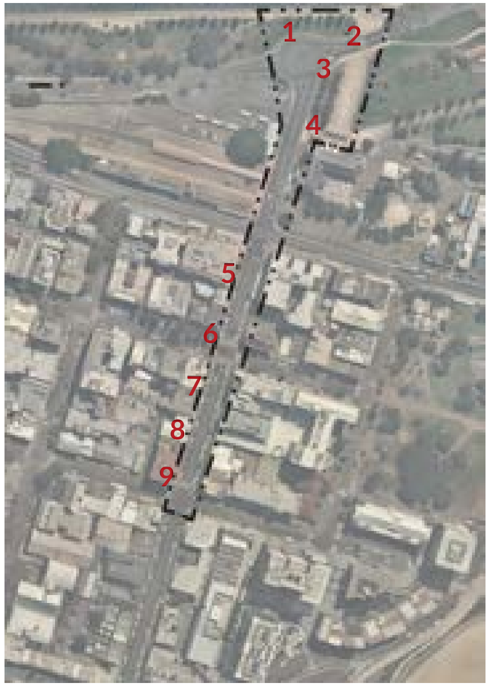
 Example still from Interactive Panorama spatialisation, detailing Watt St Panorama, Data Log Location 2

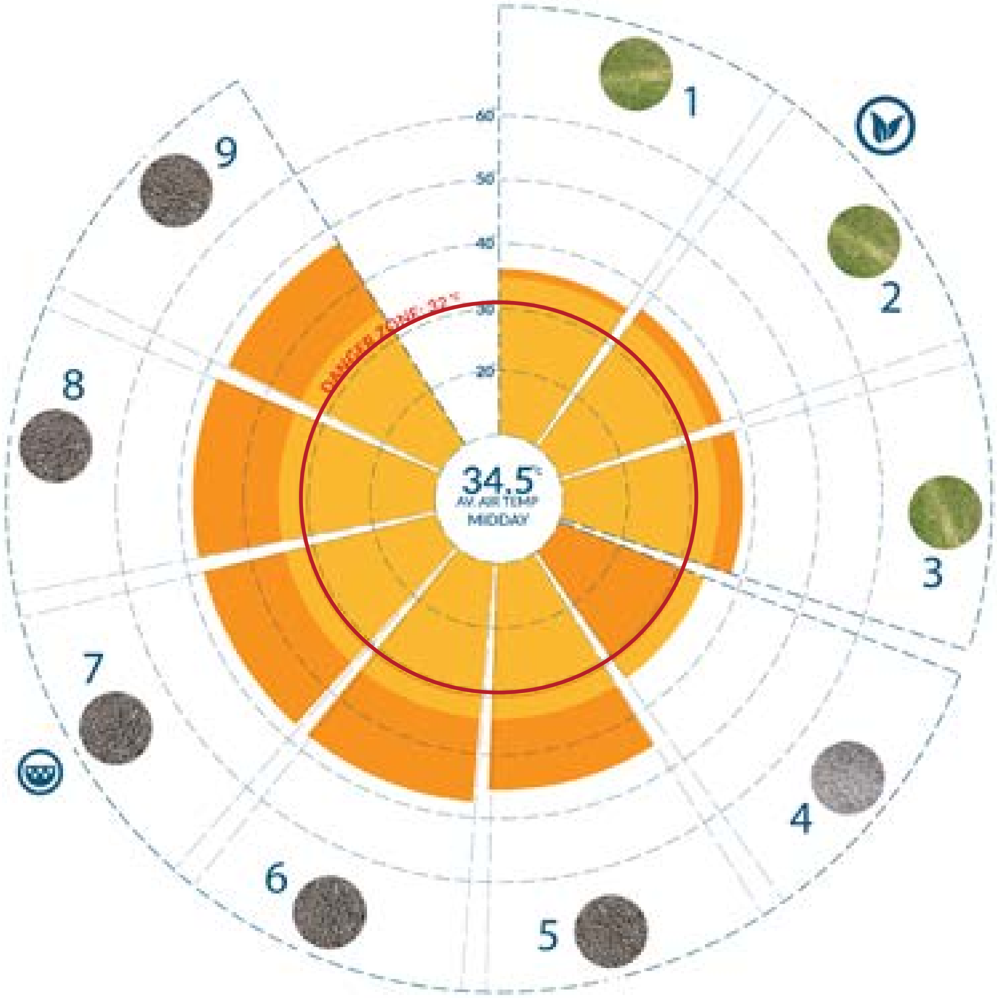
Spatialisation ALL SITES 2.2.1

WATT ST: ROSE-CHART - MORNING



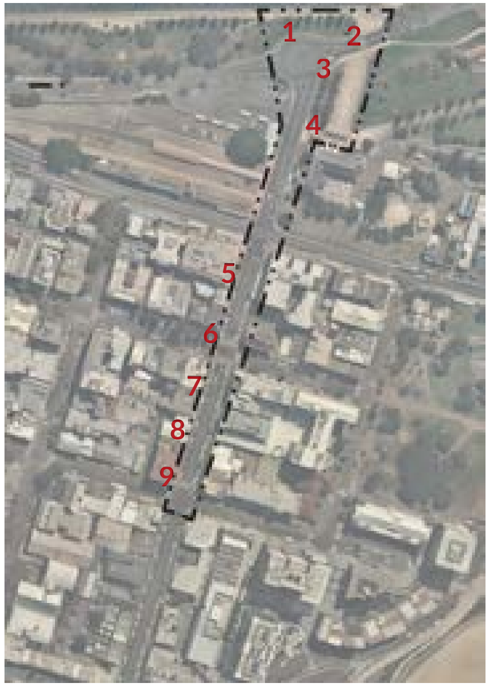
WATT ST: ROSE-CHART - MIDDAY





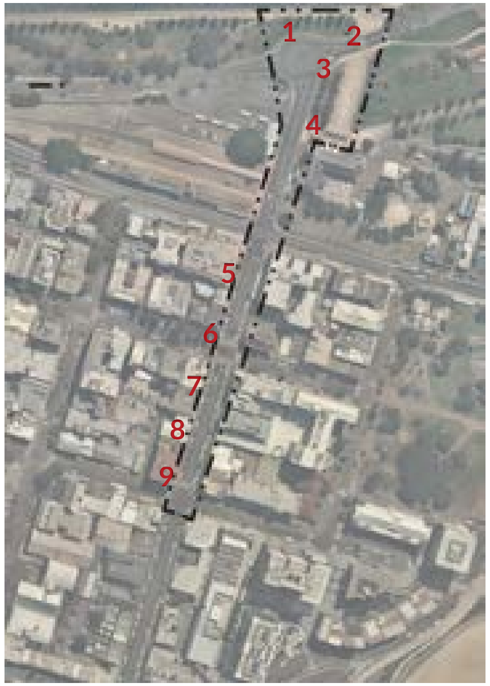
LOCATION 1. WATT STREET, NEWCASTLE

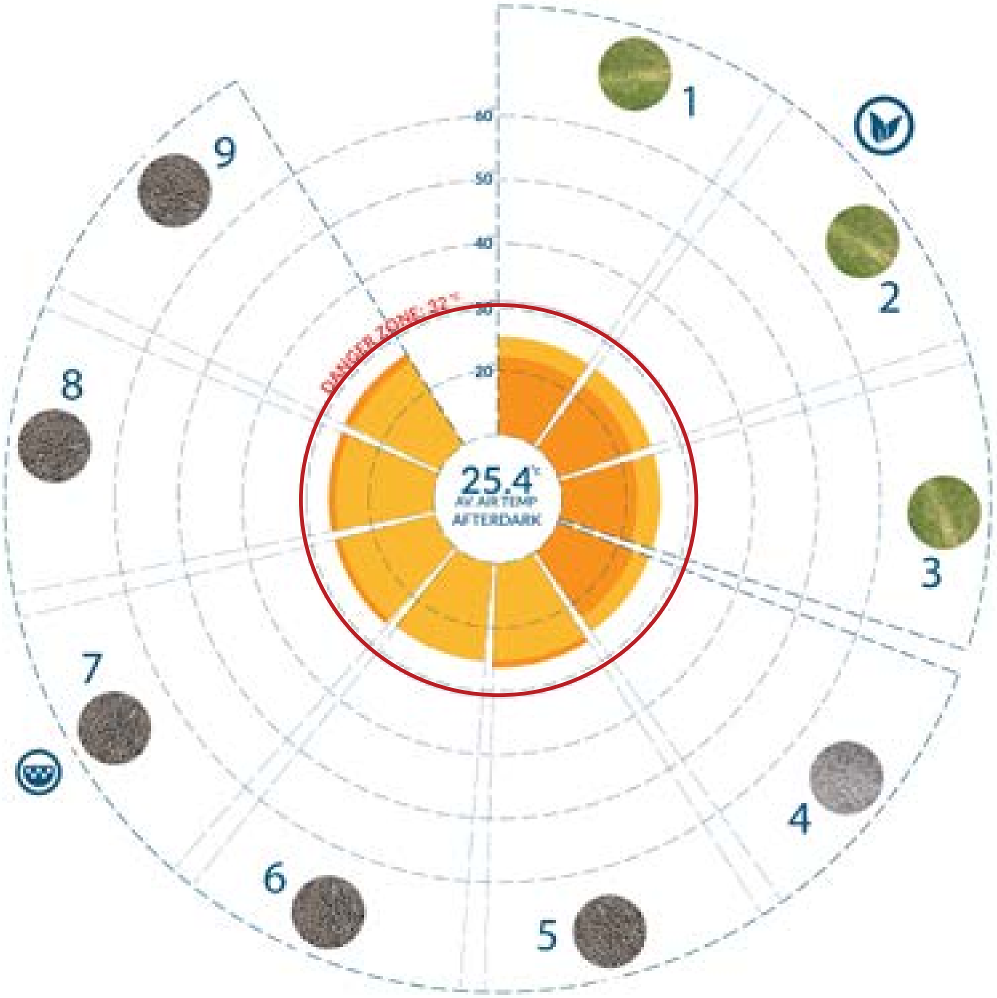
WATT ST: ROSE-CHART - AFTERNOON



LOCATION 1. WATT STREET, NEWCASTLE

WATT ST: ROSE-CHART - AFTER DARK





KEY
SURFACE TEMP. (°C)
AIR TEMPERATURE (°C)

MATERIALS

VEGETATION
DATA LOGGER 1 GRASS
DATA LOGGER 2 GRASS
DATA LOGGER 3 GRASS

HARDSCAPE (GROUND)
DATA LOGGER 4 PEBBLECRETE
DATA LOGGER 5 BITUMEN
DATA LOGGER 6 BITUMEN
DATA LOGGER 7 BITUMEN
DATA LOGGER 8 BITUMEN
DATA LOGGER 9 BITUMEN

LOCATION 1. WATT STREET, NEWCASTLE

PANORAMA: WATT ST OVERVIEW

1. WATT STREET, NEWCASTLE

Each yellow icon indicates a data collection point in the panorama. The icon itself represents the surface material selected for the temperature reading.

PANORAMA: WATT ST LOCATION 1

PANORAMA: WATT ST LOCATION 2

PANORAMA: WATT ST LOCATION 3

PANORAMA: WATT ST LOCATION 4

PANORAMA: WATT ST LOCATION 5

PANORAMA: WATT ST LOCATION 6

PANORAMA: WATT ST LOCATION 7

PANORAMA: WATT ST LOCATION 8

PANORAMA: WATT ST LOCATION 9

WORTH PLACE: ROSE-CHART - MORNING

WORTH PLACE: ROSE-CHART - MIDDAY

LOCATION 2. WORTH PLACE, NEWCASTLE

WORTH PLACE: ROSE-CHART - AFTERNOON

 Worth Place Rose-Chart, Morning

WORTH PLACE: ROSE-CHART - AFTERDARK

PANORAMA: WORTH PLACE OVERVIEW

2. WORTH PLACE, NEWCASTLE

Each yellow icon indicates a data collection point in the panorama. The icon itself represents the surface material selected for the temperature reading.

PANORAMA: WORTH PLACE LOCATION 1

PANORAMA: WORTH PLACE LOCATION 2

PANORAMA: WORTH PLACE LOCATION 3

PANORAMA: WORTH PLACE LOCATION 4

PANORAMA: WORTH PLACE LOCATION 5

PANORAMA: WORTH PLACE LOCATION 6

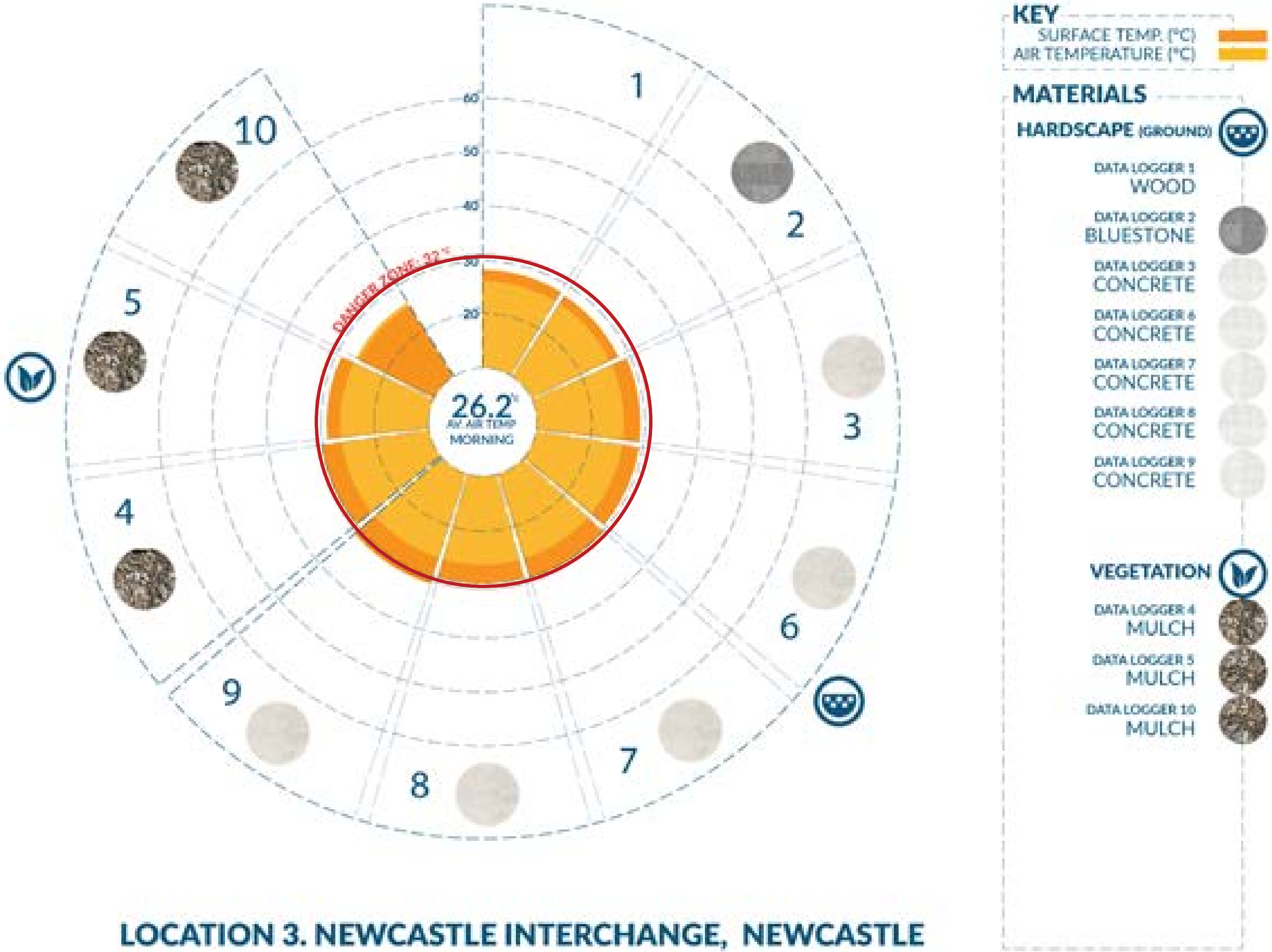
PANORAMA: WORTH PLACE LOCATION 7

PANORAMA: WORTH PLACE LOCATION 8

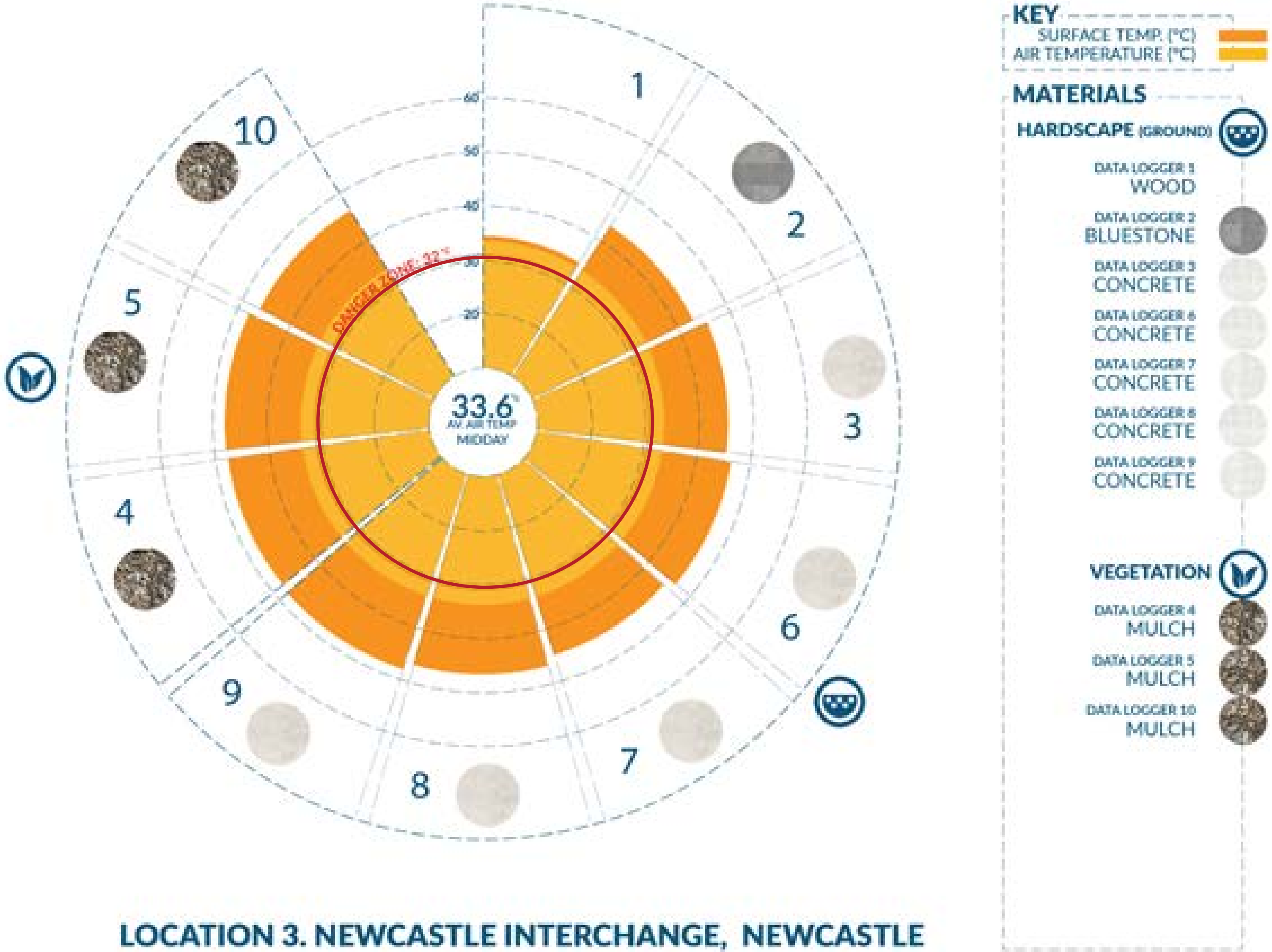
PANORAMA: WORTH PLACE LOCATION 9

PANORAMA: WORTH PLACE LOCATION 10

NEWCASTLE INTERCHANGE:
ROSE-CHART - MORNING

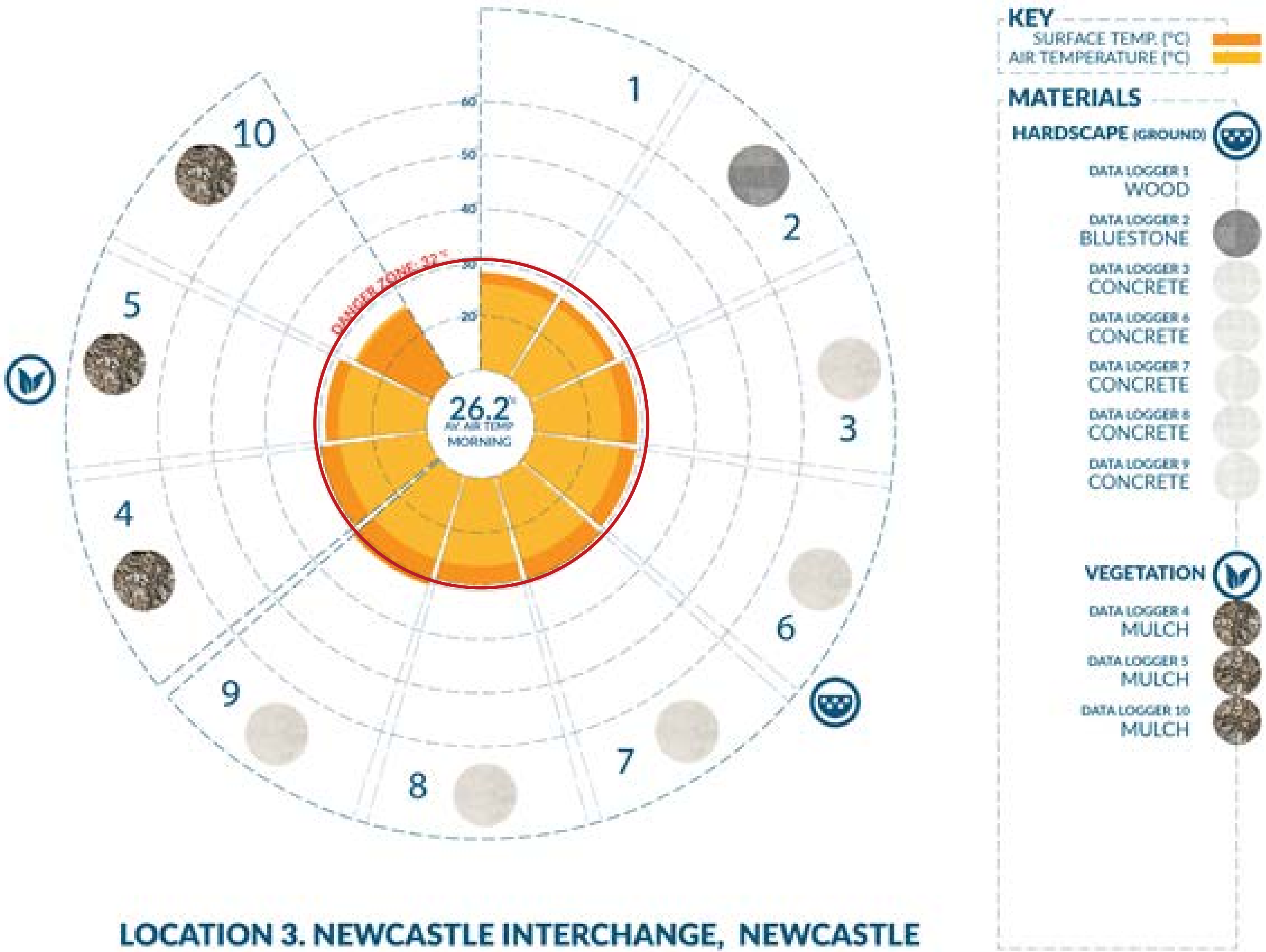


NEWCASTLE INTERCHANGE:
ROSE-CHART - MIDDAY

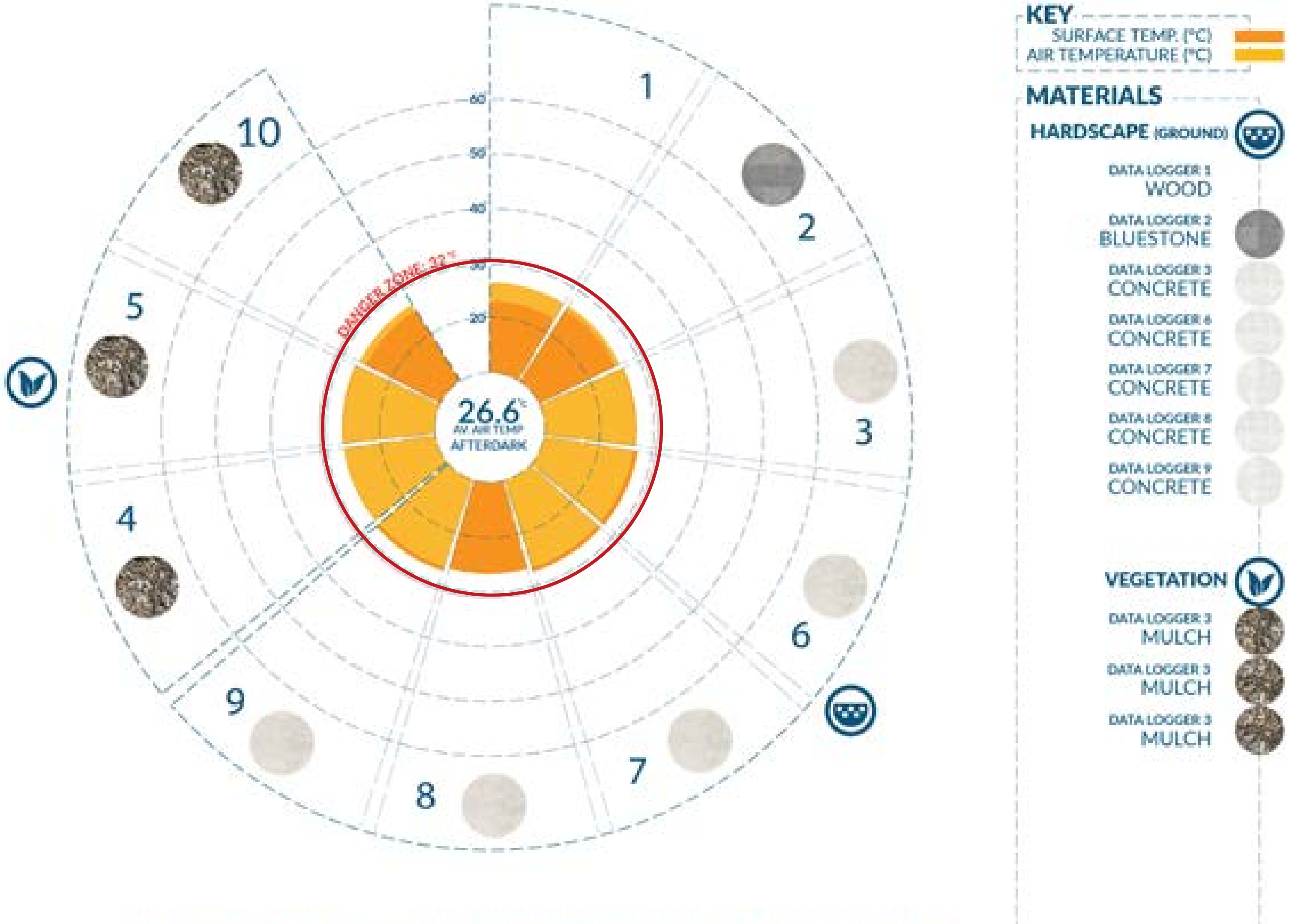


LOCATION 3. NEWCASTLE INTERCHANGE, NEWCASTLE

NEWCASTLE INTERCHANGE:
ROSECHART - AFTERNOON



NEWCASTLE INTERCHANGE:
ROSE-CHART - AFTERNOON



LOCATION 3. NEWCASTLE INTERCHANGE, NEWCASTLE

PANORAMA: NEWCASTLE INTERCHANGE OVERVIEW

3. NEWCASTLE INTERCHANGE, NEWCASTLE

Each yellow icon indicates a data collection point in the panorama. The icon itself represents the surface material selected for the temperature reading.

PANORAMA: NEWCASTLE INTERCHANGE LOCATION 1

PANORAMA: NEWCASTLE INTERCHANGE LOCATION 2

PANORAMA: NEWCASTLE INTERCHANGE LOCATION 3

PANORAMA: NEWCASTLE INTERCHANGE LOCATION 4

PANORAMA: NEWCASTLE INTERCHANGE LOCATION 5

PANORAMA: NEWCASTLE INTERCHANGE LOCATION 6

PANORAMA: NEWCASTLE INTERCHANGE LOCATION 7

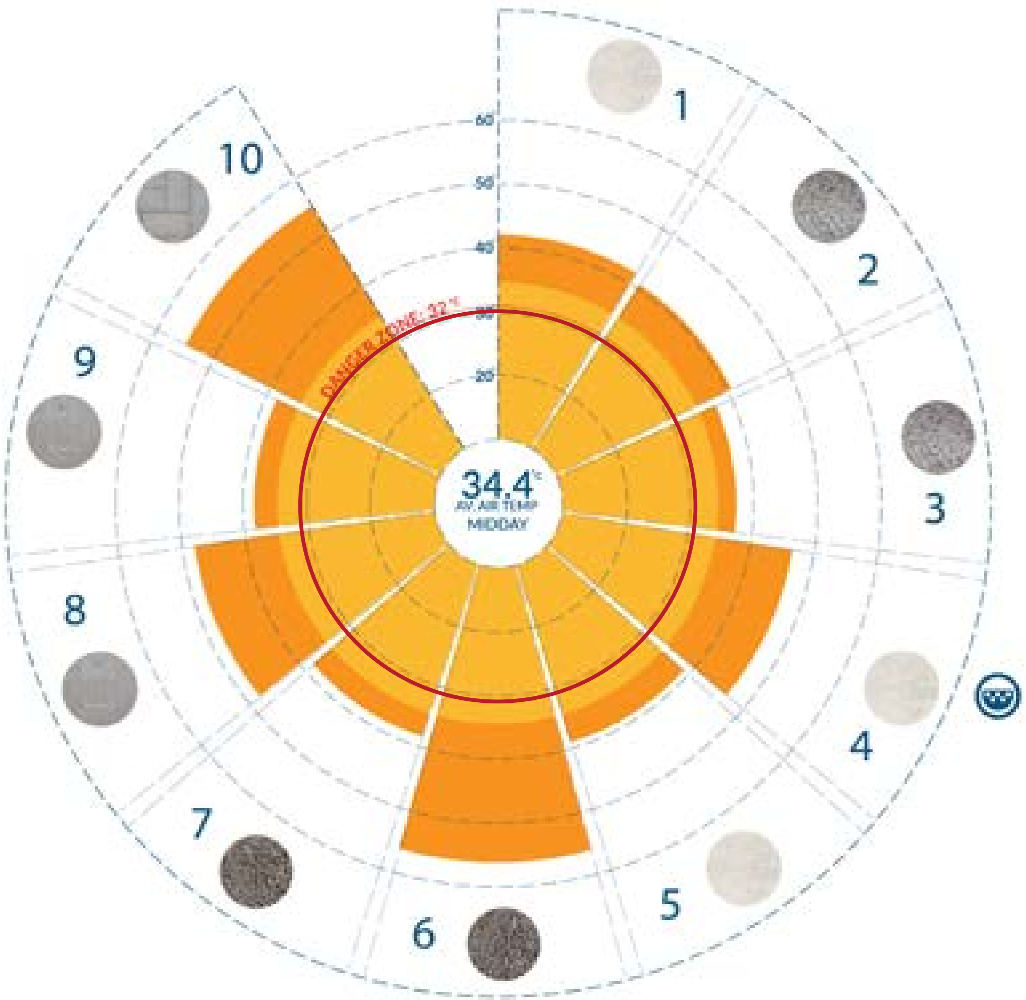
PANORAMA: NEWCASTLE INTERCHANGE LOCATION 8

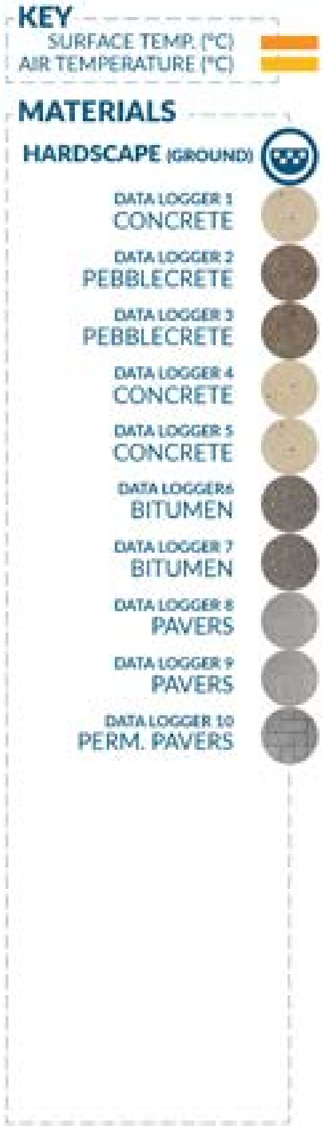
PANORAMA: NEWCASTLE INTERCHANGE LOCATION 9

PANORAMA: NEWCASTLE INTERCHANGE LOCATION 10

WALLSEND LIBRARY:
ROSE-CHART - MORNING

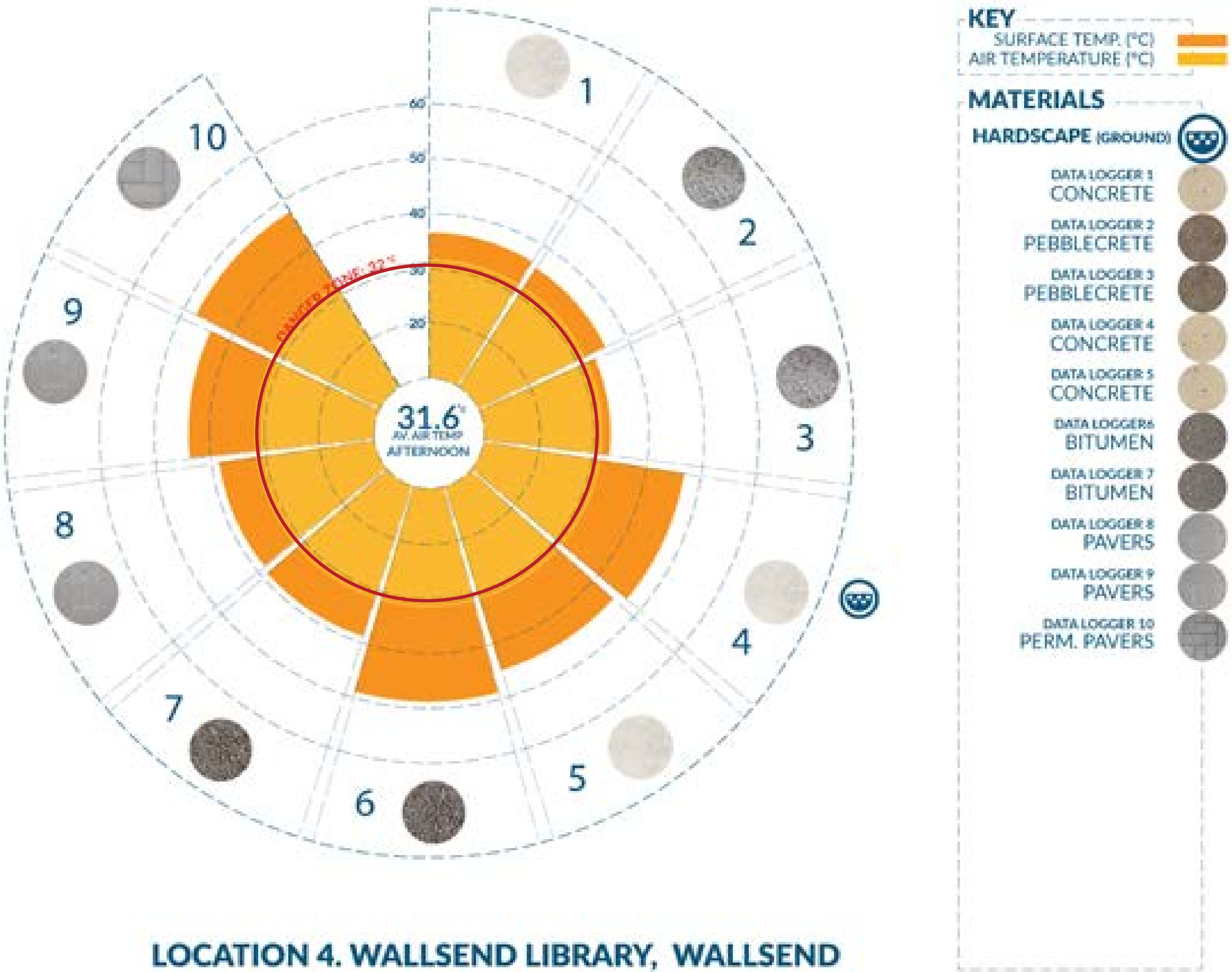
WALLSEND LIBRARY:
ROSE-CHART - MIDDAY





LOCATION 4. WALLSEND LIBRARY, WALLSEND

WALLSEND LIBRARY:
ROSE-CHART - AFTERNOON



LOCATION 4. WALLSEND LIBRARY, WALLSEND

WALLSEND LIBRARY:
ROSE-CHART - AFTER DARK

PANORAMA: WALLSEND LIBRARY OVERVIEW

4. WALLSEND LIBRARY, WALLSEND

Each yellow icon indicates a data collection point in the panorama. The icon itself represents the surface material selected for the temperature reading.

PANORAMA: WALLSEND LIBRARY LOCATION 1

PANORAMA: WALLSEND LIBRARY LOCATION 2

PANORAMA: WALLSEND LIBRARY LOCATION 3

 Wallsend Library Panorama, Data Log Location 3

PANORAMA: WALLSEND LIBRARY LOCATION 4

PANORAMA: WALLSEND LIBRARY LOCATION 5

BERESFORD AVENUE:
ROSE-CHART - MORNING

BERESFORD AVENUE:
ROSE-CHART - MIDDAY

BERESFORD AVENUE:
ROSE-CHART - AFTERNOON

BERESFORD AVENUE:
ROSE-CHART - AFTER DARK

 Beresford Ave Rose-Chart, Midday

SECTION 03.

ACTION

Mitigation of UHIE 3.0

INTRODUCTION

The synthesis and analysis of the data collection and visualisation techniques employed led ultimately to the collection of a series of strategies to mitigate Urban Heat Island Effect.

These strategies are presented in two formats:

1. A Matrix - assessing cost and time of each of the mitigation strategies in the individual kit of parts.

2. An extensive listing format described as a 'Kit of Parts'- providing further details and imagery for individual mechanisms and strategies for mitigating UHIE.

This report section focusses on the mitigation of UHIE, and looks to a wide range of techniques, structures and additions that can retrofit the existing urban fabric, assisting in the reduction of temperatures and the improvement of health and wellbeing for the users of those spaces. These are intended a preliminary list of strategies or kit of parts and will shift and adapt as new technologies emerge. The matrix and the kit of parts have been added to, shifted and rigorously interrogated during the Co-Design workshops, and future iterations would incorporate the expertise and experience of NCC staff across a range of departments.

MATRIX:
MITIGATION MEASURES COMPARISON

The Matrix is the individual kit of parts organised in a table using Cost vs Time. The matrix format enables comparisons across the individual UHIE solutions, strategies and measures. The research team deliberately left open spaces so that council and others could add parts which emerged during the Co-design Workshop and further discussions. The matrix is presented before each individual solution in this report, to provide a holistic understanding across mitigation techniques. Each square of the matrix is hot-linked the individual strategy or solution page which has further information on that measure. (The collection we have termed the kit of parts.)

The kit of parts acts as a 'swatch' to be applied to a wide variety of sites and situations to mitigate UHIE. The matrix serves as a set of tools that are at the Councils' disposal to combat increasing temperatures and improve the liveability, vibrancy and safety of Newcastle City and its locale. The following matrix is a snapshot of how a comprehensive 'kit of parts' might be formatted to clearly demonstrate a range of techniques, price ranges and establishment time frames. It provides a framework that can be built upon as technologies and methodologies emerge in the future.

The items have been broken down into categories based on the pre established surface types, as identified through the icons:

1. Hardscapes (Ground plane)

2. Hardscape (Vertical)

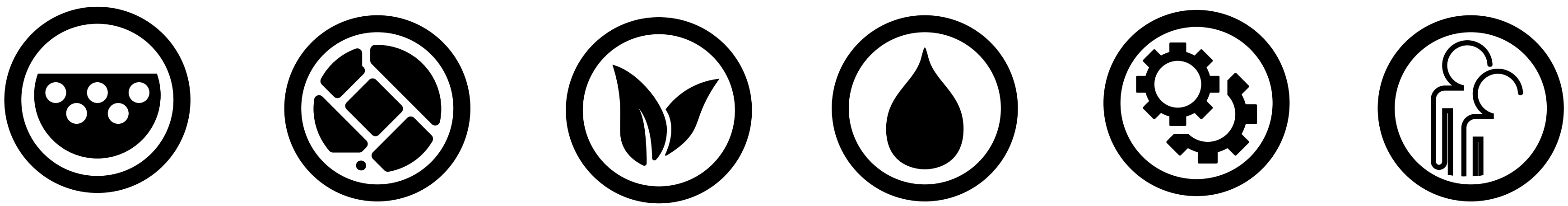
3. Vegetation

4. Technology & Systems (Smart City)

5. Water for Urban Cooling

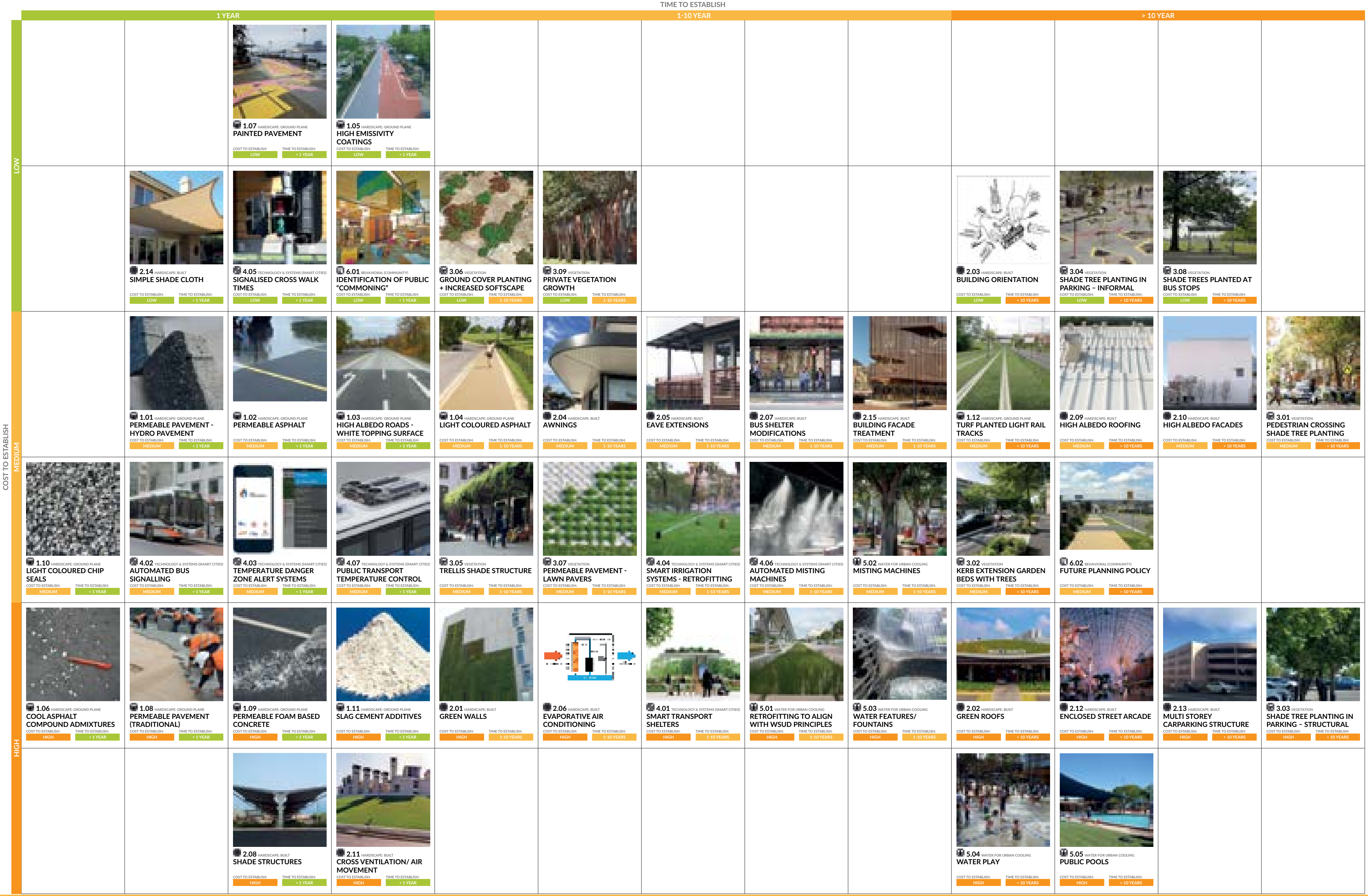
6. Behavioural (Commoning)

HARDSCAPE (ground plane) | **HARDSCAPE (vertical)** | **VEGETATION** | **WATER** | **TECHNOLOGY** | **BEHAVIOURAL**



MATRIX – STRATEGIES FOR MITIGATING UHIE

COST TO ESTABLISH vs TIME TO ESTABLISH

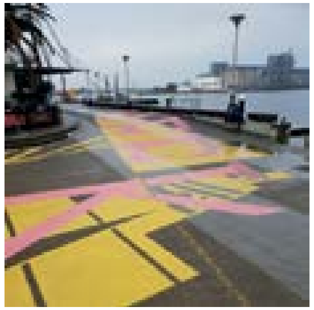


Matrix - exhibting the kit of parts organised to reflect their cost vs the time taken to establish/come into full effect.

MATRIX:
SAMPLE OF LOW COST + < 1 YEAR MEASURES

1 YEAR

LOW



1.07 HARDSCAPE: GROUND PLANE
PAINTED PAVEMENT
COST TO ESTABLISH: LOW
TIME TO ESTABLISH: < 1 YEAR

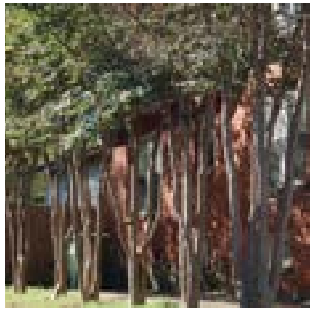
1.05 HARDSCAPE: GROUND PLANE
HIGH EMISSIVITY COATINGS
COST TO ESTABLISH: LOW
TIME TO ESTABLISH: < 1 YEAR

2.14 HARDSCAPE: BUILT
SIMPLE SHADE CLOTH
COST TO ESTABLISH: LOW
TIME TO ESTABLISH: < 1 YEAR

4.05 TECHNOLOGY & SYSTEMS (SMART CITIES)
SIGNALISED CROSS WALK TIMES
COST TO ESTABLISH: LOW
TIME TO ESTABLISH: < 1 YEAR

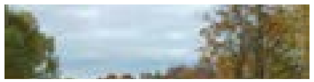
6.01 BEHAVIORAL (COMMUNITY)
IDENTIFICATION OF PUBLIC “COMMONING”
COST TO ESTABLISH: LOW
TIME TO ESTABLISH: < 1 YEAR

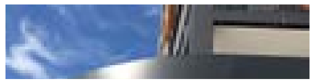
3.06 VEGETATION
GROUND COVER PLANTING + INCREASED SOFTSCAPE
COST TO ESTABLISH: LOW
TIME TO ESTABLISH: 1-10 YEARS



3.09 VEGETATION
PRIVATE VEGETATION GROWTH
COST TO ESTABLISH: LOW
TIME TO ESTABLISH: 1-10 YEARS







Matrix - exhibting the kit of parts organised to reflect their cost vs the time taken to establish/come into full effect.

MATRIX:
SAMPLE OFHIGH COST + 10 + YEAR MEASURES

4.06 TECHNOLOGY & SYSTEMS (SMART CITIES)
AUTOMATED MISTING MACHINES
COST TO ESTABLISH: MEDIUM
TIME TO ESTABLISH: 1-10 YEARS

5.02 WATER FOR URBAN COOLING
MISTING MACHINES
COST TO ESTABLISH: MEDIUM
TIME TO ESTABLISH: 1-10 YEARS

3.02 VEGETATION
KERB EXTENSION GARDEN BEDS WITH TREES
COST TO ESTABLISH: MEDIUM
TIME TO ESTABLISH: > 10 YEARS

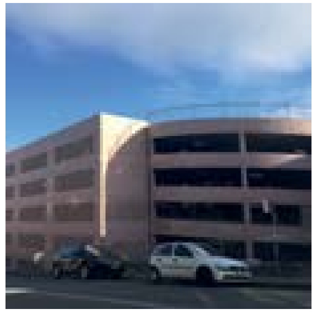
6.02 BEHAVIORAL (COMMUNITY)
FUTURE PLANNING POLICY
COST TO ESTABLISH: MEDIUM
TIME TO ESTABLISH: > 10 YEARS

5.01 WATER FOR URBAN COOLING
RETROFITTING TO ALIGN WITH WSUD PRINCIPLES
COST TO ESTABLISH: HIGH
TIME TO ESTABLISH: 1-10 YEARS

5.03 WATER FOR URBAN COOLING
WATER FEATURES/ FOUNTAINS
COST TO ESTABLISH: HIGH
TIME TO ESTABLISH: 1-10 YEARS

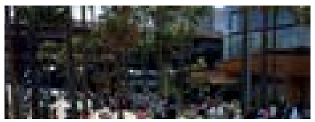
2.02 HARDSCAPE: BUILT
GREEN ROOFS
COST TO ESTABLISH: HIGH
TIME TO ESTABLISH: > 10 YEARS

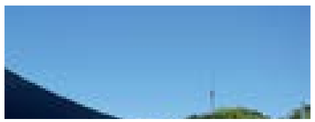
2.12 HARDSCAPE: BUILT
ENCLOSED STREET ARCADE
COST TO ESTABLISH: HIGH
TIME TO ESTABLISH: > 10 YEARS



2.13 HARDSCAPE: BUILT
MULTI STOREY CARPARKING STRUCTURE
COST TO ESTABLISH: HIGH
TIME TO ESTABLISH: > 10 YEARS

3.03 VEGETATION
SHADE TREE PLANTING IN PARKING – STRUCTURAL
COST TO ESTABLISH: HIGH
TIME TO ESTABLISH: > 10 YEARS





KIT OF PARTS:
EXPLORATION OF MITIGATION MEASURES

The following kit of parts is a culmination of the literature review undertaken on the topic of UHIE.

These are a series of strategies, measures, and techniques that have been implemented both nationally and internationally to combat UHIE. These have been broken into the six categories represented within the icons:

1. **Hardscapes (Ground plane)**
2. **Hardscape (Vertical)**
3. **Vegetation**
4. **Technology & Systems (Smart City)**
5. **Water for Urban Cooling**
6. **Behavioural (Commoning)**

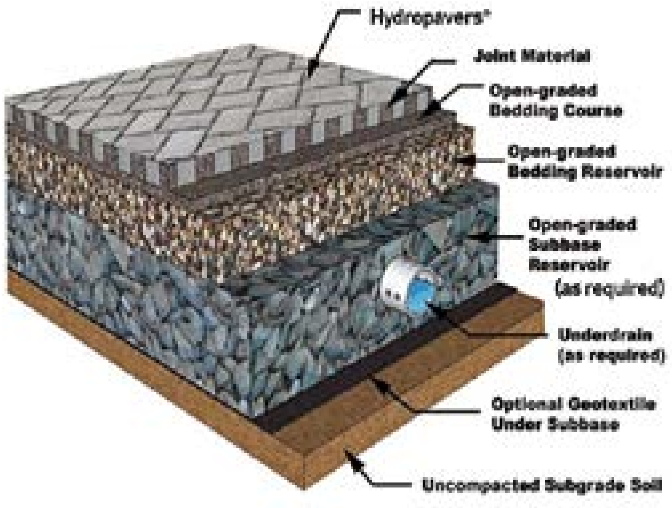
These strategies and mitigation techniques are a based on the literature review and represent a small fraction of the methods available to council to combat rising temperatures. Further information has been linked ot each material, and a thorough analysis of installation requirements and thermal performance should be undertaken prior to implementation.

This aspect of our research was formed specifically with the co-design process in mind, seeking to prompt robust discussion about the suitability of the proposed strategies and inform future projects seeking to Mitigate UHIE.

The barometer of cost and time applied to each strategy is based on cost to establish (Initial upfront expenditure) , and time to establish (construction time/period until UHIE mitigation comes into affect) All techniques are viewed through the lens of retrofitting (not green field development), as the five sites studied had existing public space amenities and would therefore require an adaptive approach vs a completely new urban design. That said, the NCC is actively engaging in placemaking and neighborhood centre updates so there maybe cause for larger scaled implementation projects.

1. HARDSCAPE (GROUND PLANE)

1.01 HARDSCAPE: GROUND
POROUS PAVEMENT - HYDRO PAVEMENT



COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

< 1 YEAR

KEY FEATURES:

- **Increases permeable surface of the landscape, increasing water absorption and retention.**
- **Evaporation of water from the pavers can help regulate surface temperatures and humidity mitigating Urban Heat Island Effect.**
- **100% permeable across their surface and their body - function as a sponge that the initial 6mm of rain is absorbed within the paver and returned to the environment via evapotranspiration.**

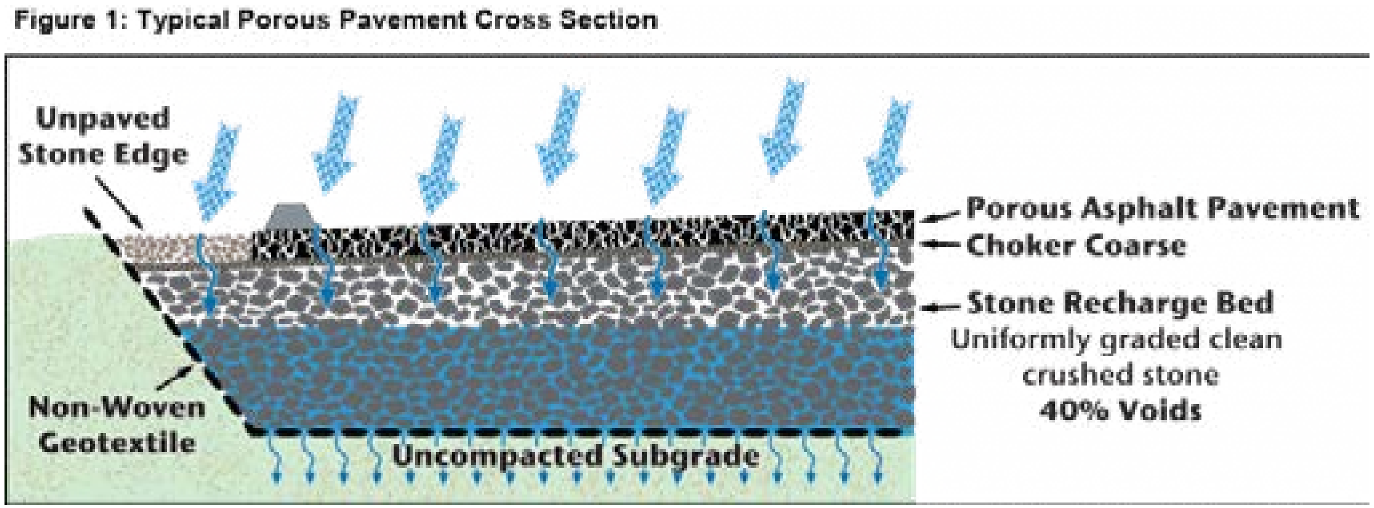
FURTHER INFO:

- **Hydro Pavers Australia**
  Hydropavers.com.au

 Porous Paving,
Image Source: Hydropavers Australia

1.02 HARDSCAPE: GROUND

PERMEABLE ASPHALT



COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

< 1 YEAR

KEY FEATURES:

- Increases permeable surface of the landscape, increasing water absorption and retention.
- Cools storm water temperature during summertime before discharge and mitigates heat island effects (Lebens 2012).
- Improves water and oxygen transfer to nearby plant roots (CTC & Associates 2012)

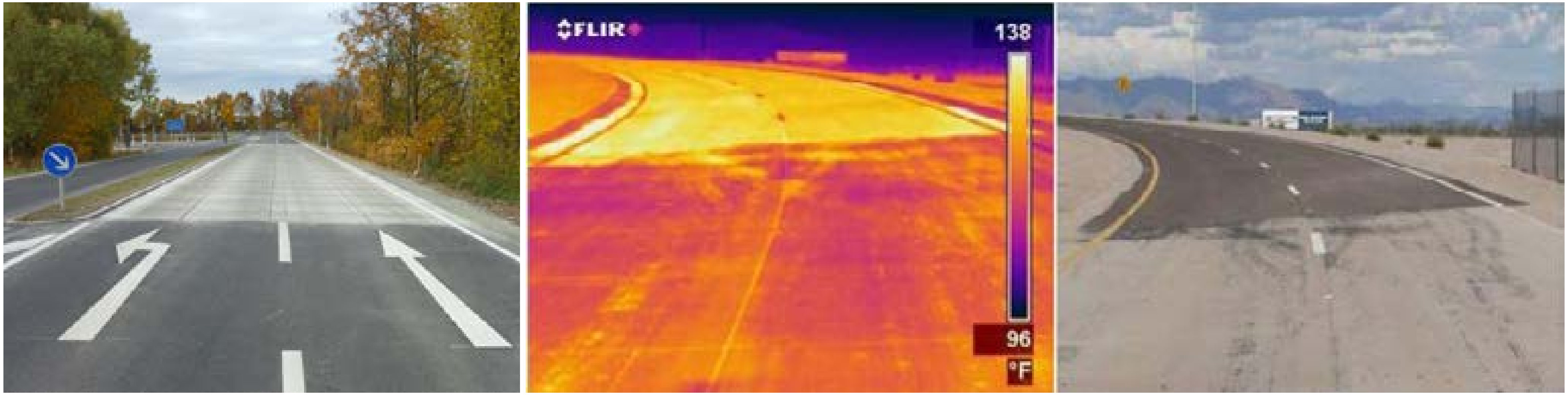
FURTHER INFO:

- Melbourne Water: https://www.melbournewater.com.au/planning-and-building/stormwater-management/options-treating-stormwater/porous-paving
- National Asphalt Pavement Association: http://store.asphaltpavement.org/index.php?productID=920
- US Department of Transportation, Federal Highway Administration: https://www.fhwa.dot.gov/pavement/

Permeable Asphalt in Use (LHS), Technical Section (RHS)
Image Source: National Asphalt Pavement Association

1.03 HARDSCAPE: GROUND

HIGH ALBEDO ROADS - WHITE TOPPING SURFACE



COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

< 1 YEAR

KEY FEATURES:

- **Reduces energy in the form of heat from being absorbed into pavement and transferring back into the atmosphere.**
- **Can be laid over existing road and car parking base.**
- **Achieves atmospheric cooling while also acting to stabilise damaged road surfaces.**

FURTHER INFO:

- **EPA:** https://www.epa.gov/sites/production/files/2014-06/documents/coolpavescompendium.pdf
- **Lawrence Berkely National Laboratory:** https://heatisland.lbl.gov/coolscience/cool-pavements

 High Albedo Roads in use (LHS, RHS) Thermal Imaging (CENTRE),
Image Source: Lawrence Berkely National Laboratory

1.04 HARDSCAPE: GROUND
LIGHT COLOURED ASPHALT

COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

1-10 YEARS

KEY FEATURES:

- Reduces energy in the form of heat from being absorbed into pavement and transferring back into the atmosphere.
- Achieves atmospheric cooling while also acting to stabilise damaged road surfaces.

FURTHER INFO:

- Lawrence Berkely National Laboratory https://newscenter.lbl.gov/2017/05/18/not-all-cool-pavements-are-created-equal/
- Landscape Architecture Magazine: https://landscapearchitecturemagazine.org/2014/03/21/war-over-cool-pavements-heats-up/

1.05 HARDSCAPE: GROUND
HIGH EMISSIVITY COATINGS



COST TO ESTABLISH:

LOW

TIME TO ESTABLISH:

< 1 YEAR

KEY FEATURES:

- High Emissivity coatings are products that increase the rate of heat transfer between the environment and solid materials.
- Results from studies showed that the application of developed coating materials could reduce the surface temperature of asphalt pavement up to 5°C.
  (Guntor, Faldhil Md Din, Ponraj, Iwao, 2014 & Wan, Hien, Ping, Aloysius, 2012)

FURTHER INFO:

- ASCE Library
  Thermal Performance of Developed Coating Material as Cool Pavement Material for
  Tropical Regions
  (Guntor, Faldhil Md Din, Ponraj, Iwao, 2014)
- PERFECT COOL:
  https://www.nippo-c.co.jp/english/images/innovative_delivery_for_pavement/green_technology/perfectcool_2.pdf
- Wan, Hien, Phay Ping, Aloysius, 2012

 High Emissivity Coatings in Use
Image Source: ASCE Library

1.06 HARDSCAPE: GROUND

COOL ASPHALT COMPOUND ADMIXTURES

COST TO ESTABLISH:

HIGH

TIME TO ESTABLISH:

< 1 YEAR

KEY FEATURES:

- Conventional asphalt pavement consists of asphalt binder mixed with aggregate. It can be modified with high albedo materials, like using light-colored aggregate, colored asphalt by pigments or sealant, or using tree resin in place of asphalt.
- Binding aggregates with resin instead of black tarmac improves its thermal performance, while also maintaining it's trafficability and water permeability.

FURTHER INFO:

- Pavement Interactive https://www.pavementinteractive.org/reference-desk/pavement-management/impacts/cool-pavementgeneral/
- Sydney Resin Stone: http://www.sydneyresinstone.com.au/features.html

Cool Asphalt Compound Admixtures (LHS, RHS)
Image Source: Pavement Interactive

1.07 HARDSCAPE: GROUND
PAINTED PAVEMENT

COST TO ESTABLISH:

LOW

TIME TO ESTABLISH:

< 1 YEAR

KEY FEATURES:

- Painting existing pavements with lighter/ high albedo colours can increase the reflectivity of the surface, and deflect radiant heat from being absorbed into the pavement.
- Can be applied to existing road, car park , playground and sporting facility pavement.
- Has the potential to increase glare in an area, so needs to be applied where topically suitable.

FURTHER INFO:

- US Landscape Architecture Magazine, 2014: https://landscapearchitecturemagazine.org/2014/03/21/war-over-cool-pavements-heats-up/
- Honeysuckle Placemaking: https://www.honeysuckleplacemaking.com/hopscotch

 Painted Pavement at Honeysuckle NSW (LHS) Painted Carpark(RHS), Image Source: UoN, US Landscape Architecture Magazine

1.08 HARDSCAPE: GROUND
PERMEABLE PAVEMENT (TRADITIONAL)

COST TO ESTABLISH:

HIGH

TIME TO ESTABLISH:

< 1 YEAR

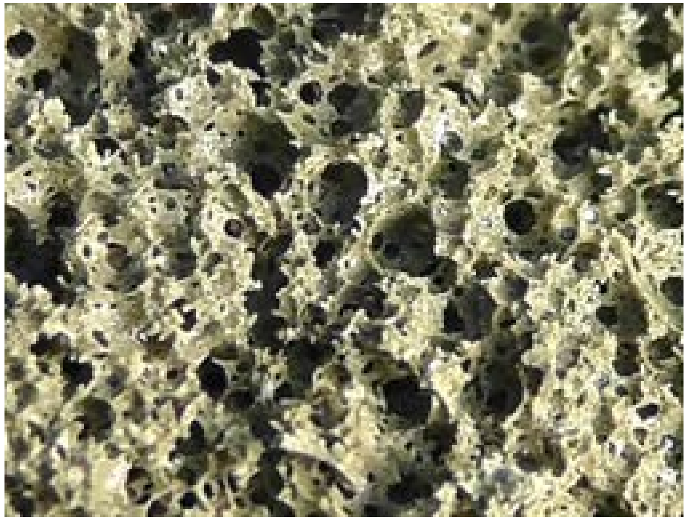
KEY FEATURES:

- Improves storm water management and retention by allowing for the infiltration of rain water.
- The retention of storm water in the landscape better services localised vegetation for the uptake for transpiration.
- Is trafficable and also appropriate for the use in pedestrian zones.
- Interlocking pavers can be easily risen in order to access services below, eradicating the need to saw-cut and back fill solid pavement surfaces.

FURTHER INFO:

- Masonry Design Magazine: http://www.masonrydesignmagazine.com/permeable-pavement-comparisons/
- Evaluating the potential benefits of permeable pavement on the quantity and quality of stormwater runoff: https://www.usgs.gov/science/evaluating-potential-benefits-permeable-pavement-quantity-and-quality-stormwater-runoff?qt-science_center_objects=0#qt-science_center_objects

1.09 HARDSCAPE: GROUND
PERMEABLE FOAM BASED CONCRETE



COST TO ESTABLISH:

HIGH

TIME TO ESTABLISH:

< 1 YEAR

KEY FEATURES:

- Foam based concrete is a cement based slurry, with a minimum of 20% (per volume) foam entrained into the plastic mortar.
- Trafficable, suitable for road bases and car parks
- Allows full water penetration, reducing water pooling hazards, slowing storm water movement and retaining more water on site for the use by localised vegetation for

FURTHER INFO:

transpiration.

-
- Science Direct, Foam Concrete as New Material in Road Constructions: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=12&ved=2ahUKEwj3l-trP3a3gAhXVWisKHaznDawQFjALegQIAxAC&url=https%3A%2F%2Fcyberleninka.org%2Farticle%2Fn%2F389133.pdf&usg=AOvVaw3iuFvpV3S-1Fl8ziXEdGewX
- Tarmac:

 Permeable Foam Based Concrete Detail (LHS) In Application (RHS)
Image Source: Tarmac

LIGHT COLOURED CHIP SEALS

COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

< 1 YEAR

KEY FEATURES:

- Chip sealing is a pavement surface treatment that combines one or more layers of asphalt with one or more layers of fine aggregate.
- A well constructed chip seal would essentially be the colour of the aggregate and could provide an effective light coloured surface.
- Chip seal is normally avoided in busy urban areas where there are closely spaced intersections and parking lanes as friction stress from vehicle turning movements may lead to a significant level of chip loss.

FURTHER INFO:

- Performance Review of the Light-coloured Pavement of the 2009 Front Street Project in Dawson City Yukon http://www.colascanada.ca/uploads/colascanada/File/2015022Strynadka596d236947d2d.pdfl/
- Science Direct: https://www.sciencedirect.com/topics/engineering/chip-seal

Image Source: Lawrence Berkely National Laboratory

1.11 HARDSCAPE: GROUND
SLAG ADDITIVES

COST TO ESTABLISH:

HIGH

TIME TO ESTABLISH:

< 1 YEAR

KEY FEATURES:

- Slag is formed as a waste product from the production of iron and copper ore in blast furnaces. It is added to cement mixtures in place of portland cement, reducing the need to manufacture portland cement (reducing carbon emissions) and lightening the colour of the cement (higher albedo performance).
- It has several workability benefits and performance such as improved strength, resistance to aggressive chemicals, and more able to be placed in hot climates.

FURTHER INFO:

- **EPA Cool Pavements Study - Task 5 (Page 20):** http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.648.3147&rep=rep1&type=pdf
- Lawrence Berkely National Laboratory: https://heatisland.lbl.gov/coolscience/cool-pavements

 Slagg Additive (LHS) In Application (RHS)
Image Source: JFE Minerals (LHS) diversifiedminerals Incorporated (RHS)

1.12 HARDSCAPE: GROUND

TURF PLANTED LIGHT RAIL TRACKS

COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

> 10 YEARS

KEY FEATURES:

- Light rail tracks interplanted with either turf or heat tolerant ground-covers.
- Vegetation watered from stormwater captured on the street and adjoining buildings and awnings.
- Requires little maintenance, as frequent vehicular movement crops grass to length and ground-cover plants maintain consistent height.
- Only requires shallow growing medium.

FURTHER INFO:

Midtown Greenway Coalition:
http://midtowngreenway.org/projects-and-programs/transit-advocacy/midtown-corridor-alternatives-analysis/

City Transport Info:
http://citytransport.info/Lawn.htm

Turf Planted Light Rail Tracks in Application (LHS, RHS)
Image Source: Midtown GreenWay Coalition(LHS), Daily Telegraph (RHS)

2. HARDSCAPE (VERTICAL)

2.01 HARDSCAPE: VERTICAL GREEN WALLS


COST TO ESTABLISH:

HIGH

TIME TO ESTABLISH:

1-10 YEARS

KEY FEATURES:

- Vegetation, either self-supporting, or structurally supported grown up the exterior facade of a building or structure.
- Reduces direct sunlight reaching the building, reducing internal heat gain.
- Reduces the reflectivity of the built form, cooling the external environment around the green wall.
- Evapotranspiration from the green wall further humidifies and cools the ambient air temperature.

FURTHER INFO:

- WSEAS Transactions on Environment and development: http://www.wseas.org/multimedia/journals/environment/2018/a545915-aay.pdf
- ANS Global: https://www.ansgroupglobal.com/living-wall/benefits/temperature

GREEN ROOFS

COST TO ESTABLISH:

HIGH

TIME TO ESTABLISH:

> 10 YEARS

KEY FEATURES:

- A green roof, or rooftop garden, is a vegetative layer grown on a rooftop.
- Green roofs provide shade, remove heat from the air, and reduce temperatures of the roof surface and surrounding air.
- Green roof temperatures can be lower than those of conventional roofs and can reduce city-wide ambient temperatures.

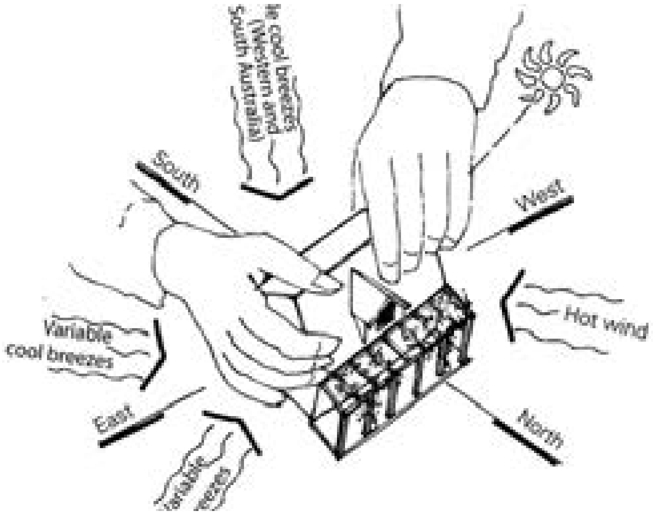
FURTHER INFO:

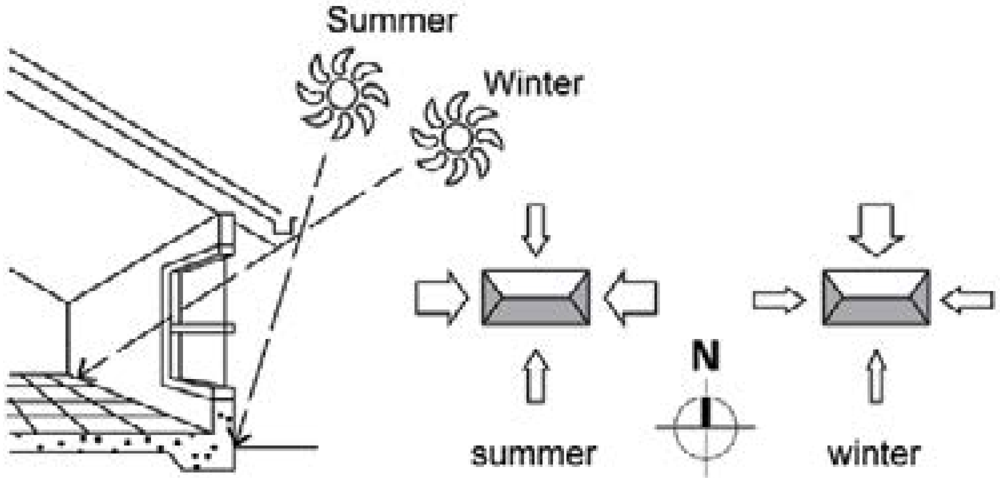
- US EPA: https://www.epa.gov/heat-islands/using-green-roofs-reduce-heat-islands
- US General Services Administration: https://www.gsa.gov/cdnstatic/The_Benefits_and_Challenges_of_Green_Roofs_on_Public_and_Commercial_Buildings.pdf

 Green Roofs in Application(LHS, RHS)
Image Source: ANS Global(LHS), Inhabit (RHS)

2.03 HARDSCAPE: VERTICAL

BUILDING ORIENTATION





COST TO ESTABLISH:

LOW

TIME TO ESTABLISH:

> 10 YEARS

KEY FEATURES:

- **Inclusion of roofs and windows and shade tree planting that best accommodates hot western sun, cool north-easterly breezesand summer and winter sun angles.**
- **Tree planting should aim to shade public open areas from the North West.**
- **Building modifications should consider the need to shelter hot afternoon Western sun.**
- **Building modifications should consider windows that face South and utilise indirect sunlight.**

FURTHER INFO:

- **Your Home: http://www.yourhome.gov.au/passive-design/orientation**

Diagrams indicating correct building orientation(LHS, RHS)
Image Source: Your Home.Gov

2.04 HARDSCAPE: VERTICAL

AWNINGS

COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

1-10 YEARS

KEY FEATURES:

- Cantilevered shade structures attached to shop-fronts to shade both the occupants of the building and pedestrians walking by.
- Cools the pavement by shading the footpath and building facade from direct sunlight.
- Protects pedestrians from the sun and its UV rays, as well as cooling the ambient temperature in its shade.

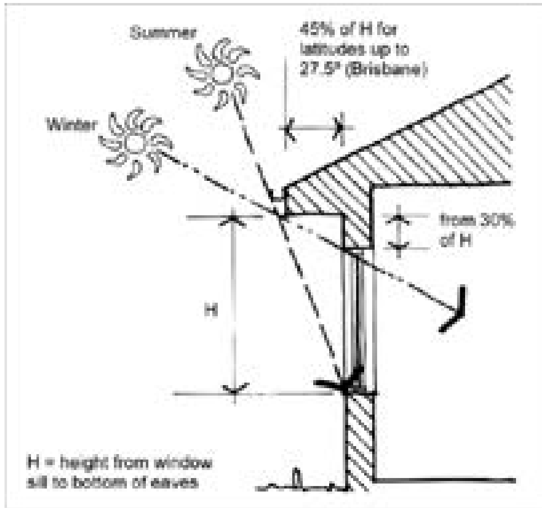
FURTHER INFO:

- Architect Luigi Rosselli provides a comprehensive overview of awnings within his work https://luigirosselli.com/news/shades-awnings-open-architecture

Awnings in Application(LHS, RHS)
Image Source: M&J Shop Awnings

2.05 HARDSCAPE: VERTICAL

EAVE EXTENSIONS



COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

1-10 YEARS

KEY FEATURES:

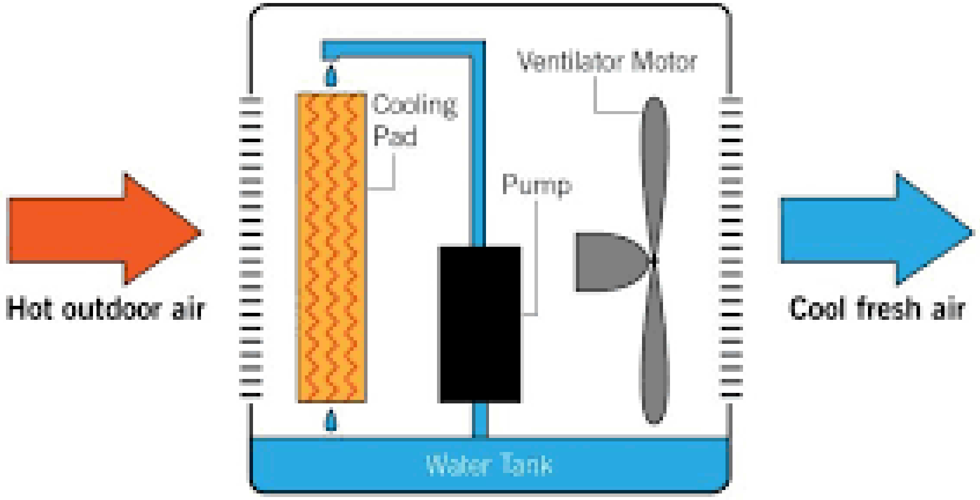
- Eaves are shade structures that most commonly, project from the roof structure of the house.
- They are intended to keep direct sunlight from hitting the walls of the building at undesirable times of the year and day - such as in Summer and in the hot afternoons.
- Eave extensions can be added retrospectively to a building, and can reduce significant heat gain in the building.

FURTHER INFO:

Your Home:
http://www.yourhome.gov.au/passive-design/orientation

Eave Extension Diagram (LHS), Eave Extension in Application (RHS)
Image Source: Your Home.Gov

2.06 HARDSCAPE: VERTICAL EVAPORATIVE AIR CONDITIONING (In place of reverse-cycle)



COST TO ESTABLISH:

HIGH

TIME TO ESTABLISH:

1-10 YEARS

KEY FEATURES:

- Evaporative Air Conditioners use evaporation of water to cool the outdoor air. An air blower draws the hot outdoor air through wet pads, which allows the air to absorb some of the pads' water as the water evaporates.
- Air that is high in humidity does not absorb the cool water as well, and so are less effective in humid environments.
- Evaporative Air Conditioners do not expell hot air into the environment, thus not further contributing to the ambient heat of the surrounding environment.

FURTHER INFO:

- Urban Heat Islands:Differentiating between the benefits nd drawbacks of using native or exotic vegetation in mitigating climate.
(Page 23):
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=2ahUKEwiO4a_GlK7gAhWUeisKHT8mBB0QFjABegQIBhAC&url=http%3A%2F%2Fro.uow.edu.au%2Fcgi%2Fviewcontent.cgi%3Farti-

 Diagrams indicating Evaporative Air Conditioning(LHS, RHS)
Image Source: Active Air Rentals

2.07 HARDSCAPE: VERTICAL
BUS SHELTER MODIFICATIONS

COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

1-10 YEARS

KEY FEATURES:

Bus shelters can be retrofitted, or re-installed to achieve greater user comfort.
Design features that the bus stops should consider include:
- Perforated facade to allow for cross ventilation and air flow.
- Insulated roof to disrupt the passage of heat into the shelter space.
- A roof canopy with overhang large enough to shade the seating within at times other than mid-day.
- Materials that do not conduct heat easily, and provide a comfortable structure to sit and lean on.

FURTHER INFO:

Climate Adapted People Shelters (CAPS):
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=2ahUKEwi4gpvUla7gAhXCbn0KHZ-LBBkQFjAAegQICBAC&url=https%3A%2F%2Fwww.yoursaypenrith.com.

Bus Shelter Modification Prototype (LHS) Modified Bus Shelter in Application(RHS)
Image Source: Australian Design Review (LHS) Manchestereveningnews.co.uk (RHS)

2.08 HARDSCAPE: VERTICAL
SHADE STRUCTURES

COST TO ESTABLISH:

HIGH

TIME TO ESTABLISH:

< 1 YEAR

KEY FEATURES:

- Stand-alone shade structures are an effective way to shade public areas of pedestrian movement and congregation.
- Often shade structures are implemented to mitigate the effects of strong sun in areas where shade trees can not be planted, or are not mature enough to provide sufficient shade.

FURTHER INFO:

- Guide to Urban Cooling Strategies (Page 31): https://apo.org.au/sites/default/files/resource-files/2017/08/apo-nid101751-1236426.pdf

 Diagrams indicating Evaporative Air Conditioning(LHS, RHS)
Image Source: Boom Festival (LHS) Malibu Shade (RHS)

2.09 HARDSCAPE: VERTICAL

HIGH ALBEDO ROOFS

COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

> 10 YEARS

KEY FEATURES:

Cool roofing products are made of highly reflective and emissive materials that can remain approximately 28-33°C cooler than traditional materials during peak summer weather.

In contrast, non-cool roof designs can reach summer peak temperatures of 66-85°C, thus creating a series of hot surfaces as well as warmer air temperatures nearby. (Konopacki, S., L. Gartland, H. Akbari, and I. Rainer. 1998)

FURTHER INFO:

Cool It. Guide to Urban Cooling (Page 16)
https://apo.org.au/sites/default/files/resource-files/2017/08/apo-nid101751-1236426.pdf

Reducing Urban Heat Islands. Compendium of strategies - Cool Roofs:
https://www.epa.gov/sites/production/files/2017-05/documents/reducing_urban_heat_islands_ch_4.pdf

High Albedo Roofing in Applicaton(LHS, RHS)
Image Source: EPA.gov (LHS) Exporters India (RHS)

HIGH ALBEDO FACADES

COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

> 10 YEARS

KEY FEATURES:

- The application of high albedo surfaces and 'cool' materials, characterized by high solar reflectance and emissivity, are advocated as a way to decrease indoor temperatures and consequently to reduce cooling loads in warm weather.
- This method is more commonly recommended to be applied to roofing, as heat and light are not reflected back into urban areas beneath the building roof line into the public realm where people spend time.

FURTHER INFO:

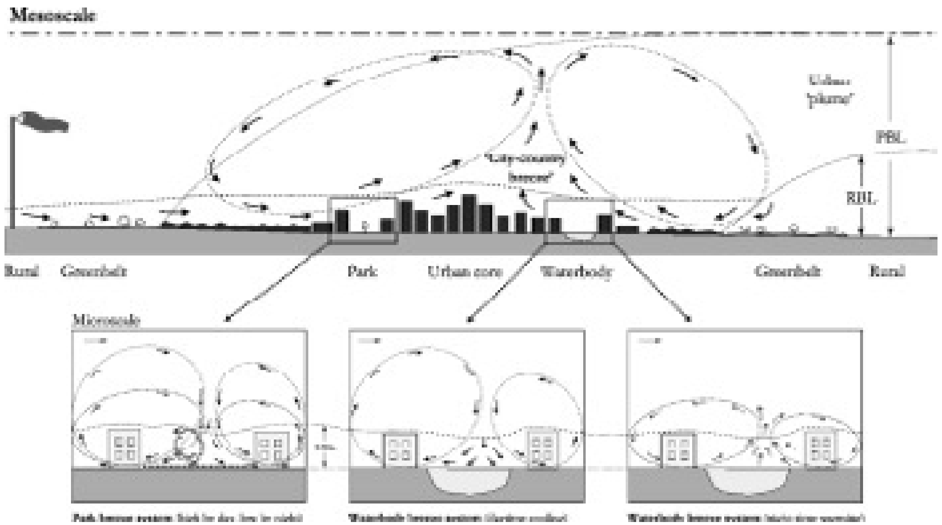
Urban Green Blue Grids:
https://www.urbangreenbluegrids.com/measures/cool-fascades-with-high-albedo/

The influence of facade properties on the canopy layer microclimate within city blocks:
https://www.google.com/url?sa=t&rct=-j&q=&esrc=s&source=web&cd=2&ved=2a-hUKEwiQ2oOVnq7gAhUVTn0KHalFAYM-QFjABegQICRAC&url=https%3A%2F%2Fams.confex.com%2Fams%2FICB2014%2Fwebpro-gram%2FManuscript%2FPaper253456%2F-GAL_10C6_extended.pdf&usg=AOvVaw-0WKLnqfJmKOeT8hiFHo1oC

 High Albedo Facade in Application (LHS), Diagrams indicating Albedo Facade(RHS)
Image Source: DEZEEN (LHS)Researchgate.com(RHS)

2.11 HARDSCAPE: VERTICAL

CROSS VENTILATION/AIR MOVEMENT



COST TO ESTABLISH:

HIGH

TIME TO ESTABLISH:

< 1 YEAR

KEY FEATURES:

- Wind speed has widely been reported to have decreased the intensity of heat island effect in urban areas. The cooling effect of the wind helps to mitigate the adverse effects of heat island on the micro climate and human thermal comfort.

- Wind catchers are structures designed to interrupt the flow of air and redirect it into the spaces that people commute and congregate.

FURTHER INFO:

Natural Ventilation: A Mitigation Strategy to Reduce Overheating In Buildings under Urban Heat Island Effect in South American Cities: https://iopscience.iop.org/article/10.1088/1757-899X/245/7/072046

Exploring wind ventilation corridors for urban heat island mitigation in Sydney, Australia: https://www.nccarf.edu.au/settlements-infrastructure/sites/www.nccarf.edu.au.settlements-infrastructure/files/Baojie%20He%20Exploring%20wind%20ventilation%20corridors%20for%20urban%20heat%20island%20mitigation%20in%20Sydney%20Australia.pdf

Cross Ventilation in Application (LHS), Diagram Illustrating Cross Ventilation (RHS)
Image Source: Red Dirt Report(LHS) Science Direct (RHS)

2.12 HARDSCAPE: VERTICAL
ENCLOSED STREET ARCADE

COST TO ESTABLISH:

HIGH

TIME TO ESTABLISH:

> 10 YEARS

KEY FEATURES:

- **The Freemont St canopy is a completely covered street arcade spanning three blocks in Las Vegas. This canopy predominantly serves as a projection/light show - it also doubles as an extremely effective shading device.**

FURTHER INFO:

Architect's Project Description https://www.jerde.com/places/detail/fremont-street-experience

Discussion on a similar canopy proposed for Darwin https://www.architectureanddesign.com.au/features/comment/requiem-or-renewal-tropical-city-darwin-cool

Freemont St, Las Vegas (LHS, CENTRE, RHS)
Image Source: Jerde

2.13 HARDSCAPE: VERTICAL MULTISTOREY CARPARKING

COST TO ESTABLISH:

HIGH

TIME TO ESTABLISH:

> 10 YEARS

KEY FEATURES:

- The stacking and shading of car parking combats UHIE in a doubled edged approach. By reducing the footprint of car parks, the amount of hard surface receiving direct sunlight is reduced.
- Deep plans create cool darker spaces. There is a potential for multiple functions to occur.
- Shaded car parking reduces the dangers of re-entering a vehicle that has been absorbing heat over the course of the day.

FURTHER INFO:

Image Source: UoN

2.14 HARDSCAPE: VERTICAL
SIMPLE SHADE CLOTH

COST TO ESTABLISH:

LOW

TIME TO ESTABLISH:

< 1 YEAR

KEY FEATURES:

- **Simple low cost shade cloth is a quick and effective measure to provide thermal comfort in the public realm.**
- **Whilst it is a short term solution, and degrades over a 3-5 year period it serves as a solid intermediate measure while larger design options are developed.**
- **Can be used across a broad range of sites.**

FURTHER INFO:

Queensland Health information re: Shading public space. https://www.health.qld.gov.au/__data/assets/pdf_file/0020/422264/20267.pdf

 Simple Shade Cloth in Application (LHS, RHS)
Image Source: Landzone (LHS), Ebay (RHS)

2.15 HARDSCAPE: VERTICAL
BUILDING FACADE TREATMENT



COST TO ESTABLISH:
MEDIUM

TIME TO ESTABLISH:
1-10 YEARS

KEY FEATURES:

- Shading of the building facade can be achieved through a wide variety of architectural systems. As an initial design feature, or through a retrofitted facade treatment, providing partial or dappled shading provides respite from UHIE and reduces the reflection and absorbtion of heat.
- The above examples highlight a snippet of the wide and varied systems - from digitally printed film wrap applied to glass, complex curtain wall systems and timber louvres.

FURTHER INFO:

Facade Shading report prepared for Melbourne City Council. https://www.melbourne.vic.gov.au/SiteCollectionDocuments/ch2-facade-shading-analysis.pdf

Image Source: Cassandra Fahey (LHS), John Wardle (CENTRE), GG Loo - Dezeen (RHS)

3. VEGETATION

3.01 VEGETATION

PEDESTRIAN CROSSING SHADE TREE PLANTING

COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

> 10 YEARS

KEY FEATURES:

- Combined Urban Cooling effects through provision of shade, evapotransporative cooling, retention and slowing of storm and ground water.
- Can be installed with Water Sensitive Urban Design (WSUD) integration.
- Provides shade for users waiting to cross road.
- Can be retro-fit into existing pedestrian crossings and hardstand kerb extensions.

FURTHER INFO:

- National Association of Transportation Officials: https://nacto.org/publications/design-guides/

Pedestrian Crossing Shade Trees in Application
Image Source: Nacto.org

3.02 VEGETATION

KERB EXTENSION GARDEN BEDS WITH TREES

COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

> 10 YEARS

KEY FEATURES:

- Combined Urban Cooling effects through provision of shade, evapotransporative cooling, retention and slowing of storm and ground water.
- Additional Pedestrian Safety benefits, as trees and planting provide a physical barrier between traffic and footpaths.
- Can be installed with Water Sensitive Urban Design (WSUD) integration.
- Additional Traffic Calming benefits.
- Shades both pedestrians and parked cars

FURTHER INFO:

- National Association of Transportation Officials: https://nacto.org/publications/design-guides/

  https://www.youtube.com/watch?v=OPQcfP0DnjA

- Sydney Streets Design Code: https://www.cityofsydney.nsw.gov.au/__data/assets/pdf_file/0011/143966/InterimSydneyStreetsDesignCode_Nov2010_Part2.PDF

Image Source: City of Sydney

3.03 VEGETATION
SHADE TREE PLANTING IN CAR PARKING LOTS - STRUCTURAL INSTALL



COST TO ESTABLISH:

HIGH

TIME TO ESTABLISH:

> 10 YEARS

KEY FEATURES:

- Combined Urban Cooling effects through provision of shade, evapotransporative cooling, retention and slowing of storm and ground water.
- Additional Pedestrian Safety benefits, as trees and planting provide a physical barrier between traffic and footpaths.
- Can be installed with Water Sensitive Urban Design (WSUD) integration.
- Additional Traffic Calming benefits.
- Shades both pedestrians and parked cars.

FURTHER INFO:

- GreenBlue Urban:
  https://greenblue.com

  https://www.greenblue.com/gb/resources/
- Dubbo Regional Council:
  http://202020vision.com.au/media/72466/tree-seminar-stockholm-presentation.pdf
- Stockholm Municipality:
  Planting Beds in the City of Stockholm -

Shade Tree Planting in Car Parks -Structural Install in Application.
Image Source: GreenBlue Urban (LHS, RHS), StrataCel (CENTRE)

3.04 VEGETATION

SHADE TREE PLANTING IN CAR PARKING LOTS - INFORMAL INSTALL

COST TO ESTABLISH:

LOW

TIME TO ESTABLISH:

> 10 YEARS

KEY FEATURES:

- Combined Urban Cooling effects through provision of shade, evapotransporative cooling, retention and slowing of storm and ground water.
- Additional Pedestrian Safety benefits, as trees and planting provide a physical barrier between traffic and footpaths.
- Additional Traffic Calming benefits.
- Shades both pedestrians and parked cars.

FURTHER INFO:

- Arquitectes: https://www.arquitectes.cat/iframes/paisatge/cat/mostrar_projecte.php?id_projecte=8083&lan=en

 Informal Shade Tree Planting in Car Park in Application
Image Source: arquitectes.com

TRELLIS SHADE STRUCTURE

COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

1-10 YEARS

KEY FEATURES:

- Combined Urban Cooling effects through provision of shade, evapotransporative cooling, retention and slowing of storm and ground water if planted into the ground.
  Can be planted into pots and risen planter beds for maximum installation ease.
- Little problem with root damage, root lift and conflict with underground services.
- Can be used as an alternative shade and shelter device to traditional bus stop shelters.

FURTHER INFO:

- CMG Landscape Architecture: https://www.cmgsite.com/project/mint-plaza/
- City of Darwin - City Centre Master plan

Trellis Shade Structure Install in Application.
Image Source: CMG Landscape Architecture

3.06 VEGETATION
GROUND COVER PLANTING + INCREASED SOFTSCAPE

COST TO ESTABLISH:

LOW

TIME TO ESTABLISH:

1-10 YEARS

KEY FEATURES:

- **Increases permeable surface of the landscape, increasing water absorption and retention.**
- **Ground cover plants absorb and hold less hest than hard-scape, and have added evapotranspirative cooling benefits.**
- **Encourages locals to maintain their planting, with the added benefit of having access to medicinal and edible plants.**

FURTHER INFO:

- **Ron Finley Gangsta Gardener: http://ronfinley.com**
- **GMC Landscape Architecture: https://www.cmgsite.com/project/crack-garden/**

 Informal Shade Tree Planting in Car Park in Application
Image Source: Ron Finley Project Las Angeles (LHS), GMC Landscape Architecture

3.07 VEGETATION

PERMEABLE PAVEMENT - LAWN PAVERS

COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

1-10 YEARS

KEY FEATURES:

- Increases permeable surface of the landscape, increasing water absorption and retention.
- Ground cover plants absorb and hold less heat than hard-scape, and have added evapotranspirative cooling benefits.
- Turf lawn in mid-summer can be 10° cooler than bare earth, 20° cooler than asphalt, concrete or pebble mulch and 40° cooler than synthetic turf. (Turf Australia)

FURTHER INFO:

- Turf Australia: Turfaustralia.com.au

Permeable Lawn pavers in Application.
Image Source: Godelmann (LHS), ABG Geosynthetics (RHS)

3.08 VEGETATION

SHADE TREES PLANTED AT BUS STOPS

COST TO ESTABLISH:

LOW

TIME TO ESTABLISH:

> 10 YEARS

KEY FEATURES:

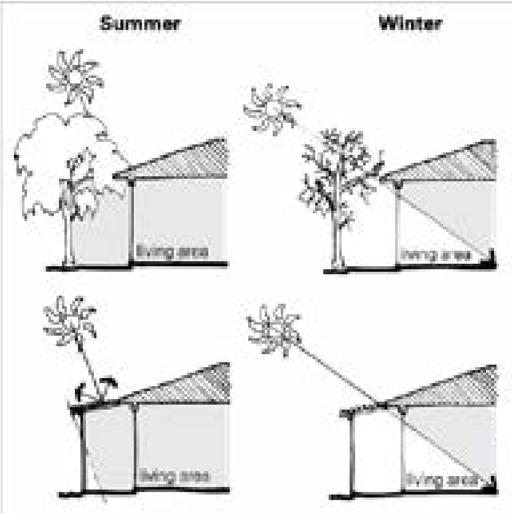
- Increases shade of the bus shelter structure, reducing direct sunlight hitting and heating the bus shelter structure.
- Cools the ambient air temperature of the surrounding environments through evapotranspiration.
- Reduces the perceived wait time for bus arrival. (Lagune-Reutler, Guthrie, Fan & Levinson, 2015)

FURTHER INFO:

- JCDecaux - Mobility and Trends https://www.jcdecaux.com/mobility-trends
- Ashfield Street Tree Strategy (Planting Street Trees near bus stops pg. B-14)
- Transit riders' perception of waiting time and stops' surrounding environments (Lagune-Reutler, Guthrie, Fan & Levinson, 2015)

 Informal Shade Tree Planting in Car Park in Application
Image Source: jcdecaux.com (LHS), aluminiumoffshore.com (RHS)

3.09 VEGETATION
PRIVATE VEGETATION GROWTH



COST TO ESTABLISH:

LOW

TIME TO ESTABLISH:

1-10 YEARS

KEY FEATURES:

- To reduce unwanted glare and heat gain, use plants to shade buildings, particularly windows.
- Evergreen plants are recommended for hot humid and some hot dry climates.
- For all other climates use deciduous vines or trees to the north, and deciduous or evergreen trees to the east and west.

FURTHER INFO:

- Yourhome Guide to Environmentally Sustainable Homes: Yourhome.gov.au
- Tree Planting lowers power bills: https://articles.extension.org/pages/70092/tree-planting-for-lower-power-bills

Diagram of benefits of Private Vegetation growth (LHS), Private Vegetation in Application (RHS)

4. TECHNOLOGY & SYSTEMS (SMART CITY)

SMART TRANSPORT SHELTERS

COST TO ESTABLISH:

HIGH

TIME TO ESTABLISH:

1-10 YEARS

KEY FEATURES:

- Integrated Environmental Monitoring Systems (EMS) that monitor real time exposure to
pollutants and climatic conditions. This information initiates public announcement systems which telegraphs tips for staying cool.
- Contains interactive maps which are used to highlight areas of events, public cool places and bus wait times.
- Integrated climatic control, including solar powered heating and cooling.

FURTHER INFO:

- Climate Adapted People Shelters, Western Sydney University: https://www.westernsydney.edu.au/__data/assets/pdf_file/0003/1480323/CAPS_Research_Final.pdf
- Techbriefs: https://contest.techbriefs.com/2017/entries/electronics-sensors-iot/8202

Image Source: Gulf News (LHS), Design4Sustainibility (CENTRE), EyeStop.com (RHS)

4.02 TECHNOLOGY & SYSTEMS (SMART

AUTOMATED BUS SIGNALLING

COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

< 1 YEAR

KEY FEATURES:

- Allows bus users to observe which buses are arriving without having to leave the protection of the shelter structure.
- Electronic bus signaling system that is engaged using either smart-phone technology or smart transport shelter alert systems.

FURTHER INFO:

- Fast Company - Fast Cities https://www.fastcompany.com/40444021/automated-buses-are-here-now-we-have-to-decide-how-they-will-reshape-our-cities
- Temaskek: https://www.temasek.com.sg/en/news-and-views/stories/future/safe-and-cool-bus-stop.html

 Automated Bus Signalling in Use.
Image Fastcompany.com (LHS), wikipedia.com (RHS)

4.03 TECHNOLOGY & SYSTEMS (SMART TEMPERATURE DANGER ZONE ALERT SYSTEMS

COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

< 1 YEAR

KEY FEATURES:

- Extreme weather warning alert system broadcasted via smart-phone applications and smart cities infrastructure.
- Alerts people on predicted heat-wave events to allow individuals and businesses to better plan their activity and movement based on predicted weather conditions and safe work environments.
- Provides additional information based on user location and acts as a directory to find locations and services which are deemed as 'cool.'

FURTHER INFO:

Climate Action Moreland:
https://climateactionmoreland.org/2015/01/04/heatwaves-and-victorias-heat-health-alert-warning-system/

Bereau of Meteorology:
http://www.bom.gov.au/australia/heatwave/

Emergency Management Victoria:
https://www.emv.vic.gov.au/news/victorias-fire-and-emergency-app-reaches-peak-ahead-of-heatwave

Image Source: BBC (LHS), env.vic.gov.au (RHS)

SMART AUTOMATED IRRIGATION SYSTEMS - RETROFITTING

COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

1-10 YEARS

KEY FEATURES:

- Automated Digital monitoring of soil moisture levels in public green areas and planter beds allows real-time data to be collected on the need for irrigation of these areas. This prevents over-watering and water wastage, and also ensures councils vegetated assets are not killed in extreme heat events and extended periods of drought.
- Automated irrigation systems ensure that the soil has a constant base level moisture level, increasing evaporative cooling, and also increasing water uptake and evapotransporative cooling via vegetation.

FURTHER INFO:

- Department of Primary Industries: https://www.agric.wa.gov.au/irrigation/soil-moisture-monitoring-fine-tune-irrigation-scheduling
- American Water Resources Association: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1752-1688.2001.tb05492.x

 Smart Automated Irrigation System
Image Source: agric.wa.gov.au (LHS), depositphotos.com (RHS)

4.05 TECHNOLOGY & SYSTEMS (SMART

SIGNALISED CROSS WALK TIME

COST TO ESTABLISH:

LOW

TIME TO ESTABLISH:

< 1 YEAR

KEY FEATURES:

- **Reducing the maximum time that pedestrians wait at signalised crosswalks to ensure that people can avoid waiting in the sun.**
- **Can be implemented to maximise pedestrian user comfort, keeping people out of all weather, not exclusively extreme heat.**
- **Has the added benefit of reducing pedestrian congestion in areas of high pedestrian traffic.**

FURTHER INFO:

- **The Guardian: https://www.theguardian.com/australia-news/2017/feb/19/australia-new-normal-47c-climate-change**

Image Source: ABC (LHS), Sydney Morning Herald (RHS)

AUTOMATED MISTING MACHINES

COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

1-10 YEARS

KEY FEATURES:

- Cools the environment by spraying fine water mist into the atmosphere and causing
evaporative cooling of both surfaces and people.
- Environmental Monitoring Sensors detect when an area reaches dangerous ambient heat levels and also monitors public usage to trigger the misting machine at any given time.

FURTHER INFO:

- PROAP: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=21&cad=rja&uact=8&ved=2ahUKEwjmuZSUns7gAhXaTX0KHYQGAqgQFjAUegQIARAB&url=https%3A%2F%2Fwww.researchgate.net%2Fpublication%2F272377951_Evaluation_of_cooling_effects_Outdoor_water_mist_fan&usg=AOvVaw1zFU1PPjE_rdy38cxf1tnk
- Department of Housing and Environmental Design: https://www.researchgate.net/publication/272377951_Evaluation_of_cooling_ef-

Image Source: Globalsources.com (LHS), pinterist.com (RHS)

4.07 TECHNOLOGY & SYSTEMS (SMART
PUBLIC TRANSPORT TEMPERATURE CONTROL


COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

< 1 YEAR

KEY FEATURES:

- As the weather heats up it is becoming increasingly important to provide places for people to experience respite from extreme heat. Ensuring that public transport does not elevate heat stress public transport users is paramount.

- Providing temperature sensors on all public transport which triggers appropriate cooling or heating within the transport carriage is essential to ensure that public transport users are not subject to extreme heat over the entire duration of their travel.

FURTHER INFO:

- ABC: https://www.abc.net.au/news/2018-04-09/cities-weather-proofing-transport-for-commuters/9633488

Image Source: urban.com.au (LHS), Denso AC (RHS)

5. WATER FOR URBAN COOLING

5.01 WATER FOR URBAN COOLING

RETROFITTING TO ALIGN WITH WATER SENSITIVE URBAN DESIGN PRINCIPLES

COST TO ESTABLISH:

HIGH

TIME TO ESTABLISH:

1-10 YEARS

KEY FEATURES:

- WSUD provides a mechanism for retaining water in the urban landscape through stormwater harvesting and reuse while also reducing urban temperatures through enhanced evapotranspiration and surface cooling.
- WSUD can provide a source of water across Australian urban environments for landscape irrigation and soil moisture replenishment to maximize the urban climatic benefits of existing vegetation and green spaces.

FURTHER INFO:

- Stormwater Victoria: https://www.stormwatervictoria.com.au/images/2018_Events/2018_Stormwater_Victoria_March_Breakfast_Seminar_Proceedings/Carol_Jadraque_-_Melbourne_Waters_Urban_Cooling_Program_-_A_Tangible_Climate_Change_Adaptation_Inititative.pdf
- CRC for Water sensitive communities: https://watersensitivecities.org.au/content/watering-our-cities-the-capacity-

WSUD In Application (LHS) Diagram explaining WSUD Principles (RHS)
Image Source: e2designlab.com (LHS), TRC (RHS)

5.02 WATER FOR URBAN COOLING
MISTING MACHINES

COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

1-10 YEARS

KEY FEATURES:

- Water is blown through misting nozzles or a centrifugal misting system, producing a fog of water droplets so fine they can barely be seen. A fan is usually located behind the high pressure mist nozzles which propell the mist into the environment.
- The water is generally cooled before being ejected, further cooling the environment.
- Often used in private outdoor dining areas, misting machines could be implemented in areas of public congregation such as bus stops and the entry to schools.

FURTHER INFO:

- The Guardian: https://www.theguardian.com/cities/2018/aug/15/what-heat-proof-city-look-like
- New Air: https://www.newair.com/blogs/learn/how-misting-fans-work

Misting Machines in Application
Image Source: jcdecaux.com (LHS), the guardian.com.au (RHS)

5.03 WATER FOR URBAN COOLING
WATER FEATURES/FOUNTAINS


COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

1-10 YEARS

KEY FEATURES:

- Provides places for people to sit, play and walk through in day-to-day activities.
- Cools the environment through evaporative cooling.
- Provides a free and accessible place for people to gather. Multi-functional in the sense that it provides opportunities for both cooling and public congregation.

FURTHER INFO:

- Urban Green Blue Grid: https://www.urbangreenbluegrids.com/measures/cooling-with-fountains/
- Foreground: https://www.foreground.com.au/environment/tackling-urban-heat-water-landscape/
- Sydney Water: https://www.sydneywater.com.au/web/groups/publicwebcontent/documents/document/zgrf/mty4/~edisp/dd_168965.

Examples of Water Features/Fountains in Use
Image Source: fiveprime.com (LHS), foreground.com (RHS)

5.04 WATER FOR URBAN COOLING

WATER PLAY

COST TO ESTABLISH:

HIGH

TIME TO ESTABLISH:

> 10 YEARS

KEY FEATURES:

- **Water play facilities located within parks, playgrounds, urban centres and retail centres for the use and amenity of children and their carers.**
- **Provides a place for children, who are particularly vulnerable to extreme heat events, to cool by directly splashing themselves with water provided for interactive play and deliberate cooling.**
- **Ellas List: https://www.ellaslist.com.au/articles/top-8-free-water-play-parks-for-kids-in-sydney**

Water Play implemented in Public Space
Image Source: Darling Quarter (LHS), landscape australia (RHS)

5.05 WATER FOR URBAN COOLING

PUBLIC POOLS

COST TO ESTABLISH:

HIGH

TIME TO ESTABLISH:

> 10 YEARS

KEY FEATURES:

- **Public pools provide areas for individuals and families, particularly those in the West of the city who don't have easy access to the beach, to cool down on hot days.**
- **Pools must have adequate shade to allow people to keep out of the sun while at places of public cooling.**
- **Public transport, entrance fees and opening hours all have to be condusive to an all-inclusive public facility.**

Public Pool Amenities

Image Source: Outdoor Design (LHS),twitter.com (RHS)

6. BEHAVIOURAL (COMMUNITY)

6.01 BEHAVIOURAL (COMMUNITY)

IDENTIFICATION OF PUBLIC COMMONING

COST TO ESTABLISH:

LOW

TIME TO ESTABLISH:

< 1 YEAR

KEY FEATURES:

- "Commoning" refers to public areas that have either been designed to accommodate numerous members of the public, or informally have become places for public congregation that are cooler, and more engaging than their own homes.
- Commoning for cooling occurs in many public places, such as shopping centres, cinemas, libraries, childcare and social facilities. People are attracted to the temperature regulated interior of these venues.
- Other forms of commoning for cooling occur in places of naturally occuring and shade water.

FURTHER INFO:

Western Sydney University, Cooling the Commons:
https://www.westernsydney.edu.au/__data/assets/pdf_file/0020/1161470/cooling-the-commons-report.pdf

Riot ACT:
https://the-riotact.com/ten-places-to-stay-cool-during-a-canberra-heatwave/192840

Places identified as 'Cool Commons'
Image Source: brewstherhjorth.com.au (LHS), JohnSpencer (RHS)

6.01 BEHAVIOURAL (COMMUNITY)

IDENTIFICATION OF PUBLIC COMMONING

COST TO ESTABLISH:

MEDIUM

TIME TO ESTABLISH:

> 10 YEARS

KEY FEATURES:

The mass removal of all vegetation from these sites, only to be replaced by juvenile, often exotic, small - mid sized tree planting will only further exasibate the effects of the Urban Heat Island. No matter the measures implemented to mitigate the affects of current heat islands, efforts will be negligible for as long as State and local governments continue to approve conventional green-field land clearing and storm-water management systems.

As greenfield residential development sites continue to spread outward from city and town centres across the region, preventative measures, as opposed to reactive measures, need to be taken in order to reduce the effects of Urban Heat Island.

FURTHER INFO:

- Parliament of Australia: https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/CCInfrastructure/Report/c04
- American Planning Association: https://search.proquest.com/openview/8612661975f355b6c5a1e6ba5cf4aec4/1?pq-origsite=gscholar&cbl=41477

Image Source: Architecture AU (LHS), TheCourierMail (RHS)

SECTION 04.

CO-DESIGN

Co-Design Workshop 4.0

INTRODUCTION - CO-DESIGN

A key goal of this research is to establish a cross institutional collaborative platform between NCC and across multiple disciplines within The University of Newcastle. The research aimed to deliver a number of data visualisations and urban solutions that were directly applicable to current Newcastle City Council Smart Cities goals and programs.

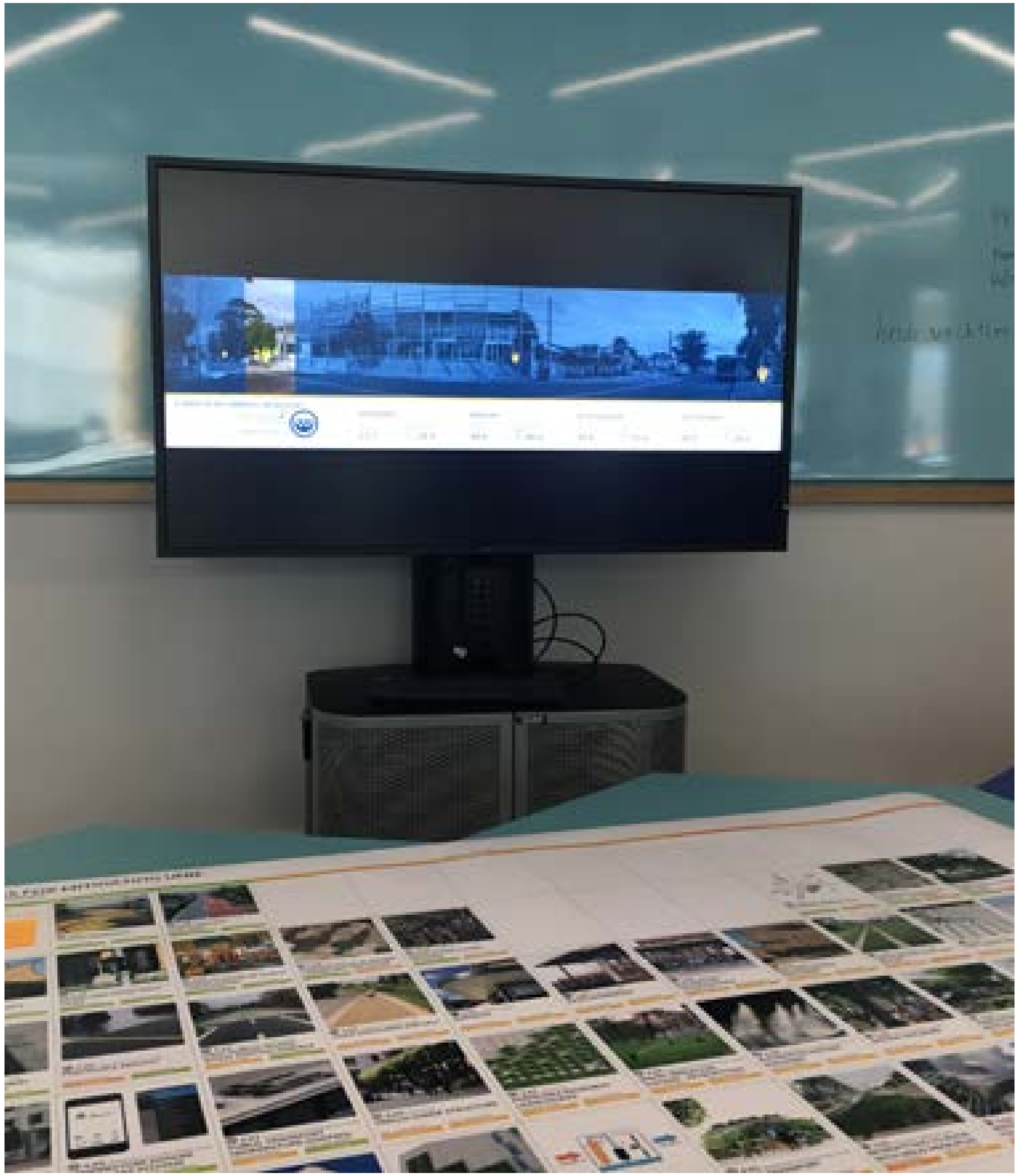
Through the inclusion of a co-design workshop as an embedded feature of the research project, the final stages of the project brought together the research undertaken by the UoN project team and the extensive body of knowledge, expertise and experience that individuals within NCC possess to inform and improve our built environments.
The underpinning ideals within co-design are those of collaboration, cooperation and community centric approaches to design and research. Incorporating the 'client', 'user', 'community', 'beneficiaries' or 'constituents' allows for a more 'consumer led' deliverable.
The specific outcomes we worked to achieve through the co-deisgn workshop process include the following:

1. **Practical, real world solutions:** Focusing on developing practical, real world solutions to issues facing individuals, families and communities.
2. **Inclusive:** Drawing on numerous perspectives, people, experts, disciplines and sectors.
3. **People centric:** While the research undertaken was extremely data heavy, the desired final outcome is a people centric set of legible, usable and interactive material relating to UHIE that can serve as an informative, useful tool for NCC into the future.

Our co-design workshop was envisioned as a space for collaboration, an opportunity to test ideas, methods and techniques and further refine research, seeking practical, inclusive solutions. We hoped to achieve shifts and leaps in our approach and thought processes to date, with the scope spanning from minor changes to radical revisions of the research to date. The Co-Design workshops and its techniques were approved through UON's Human Research Ethics Committee's processes.

The workshop was designed around the communication of the below materials, both through digital and physical means:

1. UHIE Introduction, Danger and Impacts + Project Outline
2. Data Visualisation - Scatter Graphs, Bar + Pie Charts, Plans, Aerial Photos
3. Data Spatialisation - Rose-Charts and Panoramas, Interactive PDF and printed at large scale.
4. Mitigation - Kit of Parts as A6 playing cards, Mediation Matrix printed at large scale format.



CO-DESIGN:
WORKSHOP STRUCTURE

The Co-design Workshop was broken into three separate working group sessions, each pertaining to a specific area of Newcastle LGA that was surveyed:

1. **Hunter St/Newcastle City Sites:**
2. **Wallsend**
3. **Beresfield**

Each site focused session was then broken into three sections, this was to ensure various levels of interaction and interactivity required from the participants.

Led: The introduction to the workshops was a 30 minute introduction to the research, covering the aims, methods and initial data collected.

Semi Led: Visualisations + Spatialisation of the data was then introduced, and participants were asked to interpret these methods – testing their effectiveness.

Participant Led: Participants were then broken into 2 teams and presented with a Matrix and Kit of Parts in the form of a set of playing cards – a 'game' was devised were each site is analysed and a series of mitigation playing cards (kit of parts) were applied as a mitigation technique for each site.

Each section was followed by a series of questions, that aimed to prompt discussion and critique of the information conveyed. These questions were also reflections from the research team, analysing and questioning their work and its effectiveness.
The prompting questions for each session were as follows:

Prompting Questions: Visualisation of Data

Are the graphs, pie charts, and bar chart visualisations clear in terms of the data they describe or represent?

Are there confusing aspects or things which could be clearer? Does they make the data accessible?

Does they communicate at the meta/micro levels?

We've intentionally utilised convention modes of representation for data sets are they better/more effective than an excel spreadsheet?

What other ways could this information be visualised?

Prompting Questions: Spatialisation of Data

What do these drawings mean?

Is it clear what the drawings are trying to achieve? Are they effective? (if no- then what is confusing or what is difficult to understand?)

Do they connect the data to the place / site?

For those who haven't been to the site, are they legible? And/ or do they provide orientation
to the site and the effects of UHIE?

Would your constituents understand these?

How can Smart City live data feed into these types of visualisations?

What other methods could be utilised to spatialise this data?

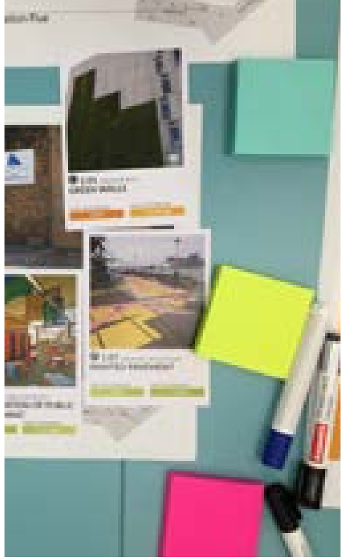
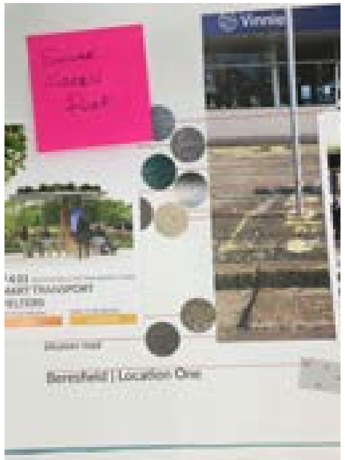
Prompting Questions: Mitigation of UHIE

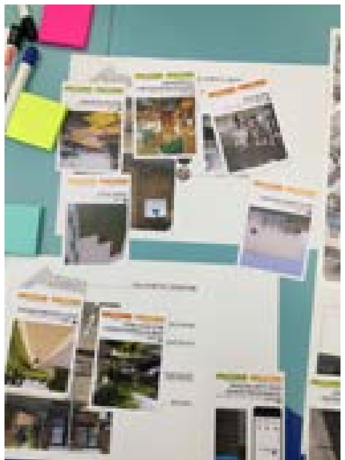
Given the conditions on site and its location (context)what short, medium or long term mitigation methods would you use?

Why have you selected this method? What other methods are not listed in the matrix?

Is this information legible and accessible? What other ways can we examine various mitigation
approaches?

These questions were presented to the participants at the conclusion of each section of the Co-Design Workshops. The following section will detail the response broadly, and provide specific responses for individual sessions.




CO Design Workshop: Participants discuss mitigation techniques through the Kit of Parts card game, Images UoN

CO-DESIGN:
WORKSHOP RESULTS

GENERAL OBSERVATIONS

The manner in which the information was released, as a slow build to revealing the results in increasingly complex ways was initially met with resistance – as the initial data visualisations were deemed to be unsatisfactory by participants who anticipated our next steps for themselves and were dissatisfied with the level of sophistication. In a scenario where verbal feedback was encouraged at each step – this created a dialogue that the research team initially struggled to keep on topic, however the foreshadowing of our next steps through the discussion of the first led session proved useful as it allowed the content to level up its engagement with the participants.

Nearly all feedback in regards to the visualisations, spatialisations and the Matrix were bound by anticipated audience. Changes that were recommended were always prefixed by who the information was to be conveyed to. It appears that as a visual and spatial means to communicate internally within NCC this research was extremely useful, however if the issue and visualisations were to be taken to the public, or conveyed to higher management or Counselors, it would need to be distilled further to communicate clearly to those unaware of UHIE and its related issues.

There was a general struggle to understand the ratio bar charts and pie charts, predominantly surrounding the percentages of materials present across the five sites in the data visualisation sessions. As the 2nd and 3rd sessions progressed the understanding increased, however it remained a contentious issue and attracted a large variety of questions. The scatter graphs proved considerably more legible than anticipated, and were understood broadly as an effective way to initially visualising the data.

The interactivity of the Matrix and the associated kit of parts playing cards proved extremely useful in triggering conversations amongst participants and researchers as to which mitigation techniques might be employed at specific sites. The interrogation of the 'cost' of each mitigation technique was a useful development – with a desire to consider cost linked with benefit, to avoid dismissing effective and long term solutions based on upfront expenditure.

General reflections on the Co-Design process and 'Where to Next' focused on how to incorporate UHIE into education, both at a broad level within the community and at a higher level within relevant tertiary courses. As the conversation around Climate Change becomes broadly dispersed and widely discussed, themes of how our built environments are contributing to rising temperatures are the next step in social awareness. To implement action on a policy level there must be a high level of constituent engagement with the issue.

There were several suggestions as to where this research could be implemented within planning processes as a training module for development application assessors, urban designers and planners and broadly across NCC.

CO-DESIGN:
HUNTER ST SESSION

HUNTER ST INTRODUCTION AND VISUALISATION OF DATA

Initial Reactions/Discussion following Presentation of Visualisation Methods:

There were initially a large amount of questions focused on the pie charts, especially questioning the way in which the prevalence of bluestone was communicated. Participants were on board with the data that was being presented, but felt that the excel generated material graphs where not accurate enough, and potentially misrepresented material qualities.
There was a robust discussion about the purpose of the data, and how to avoid presenting 'dispassionate' analysis. A need for narrative/emotive cues was highlighted as crucial in presenting data to constituents or higher management.
Some of the key queries/statements that arose are listed below:

Researcher Question:
Are these visualisations clear?
Participant Answer:

> *"The Graph/Pie Charts are very confusing. This is not a succinct way to communicate the materials radiant temperatures. The Scatter Graphs are effective as a tool to communicate internally within Council, however would fail as a tool to communicate with Constituents."*
> There was a general consensus that the graphs and maps do not 'speak' to each other enough.

Researcher Question:
Does they communicate at the meta/micro levels?
Participant Answer:

> *"No – the visualisations need greater focus on the micro. If there was a breakdown of one location, day by day it would be more effective. Communicating through a hyper specific case study vs giving a broad overview. I think that you need to visualise data to people that assumes no knowledge of the subject at all, and it needs to leverage emotion. That needs to play to their innate understanding of something - maybe the use of elemental colours that indicate levels, green, orange red. You need to couple site and data, as is you're asking the participant to marry the information. When communicating with the public you always need to be telling a story with data, it needs to lead somewhere – present it in a way that demands action. "*

HUNTER ST SPATIALISATION OF DATA

Initial Reactions/Discussions following Semi Led Presentation of Spatialisation Material:

The spatialisation received a much greater level of engagement and positive response. The ability to connect to the space in a visual manner was greatly appreciated by participants. Correlations between the Rose-Charts and the Panoramas were grasped quickly and observations as to the material quality of the streetscape were immediately voiced. The desire for a slightly simpler version, with a greater focus on icons vs listed temperatures was prevalent across all participants, as was a desire for more linear, sequential ordering of the Rose-Chart wheel.
The 32 degree 'danger zone' proved to be a contentious figure, as current Council outdoor worker policy had a much higher figure flagged as dangerous. Through a discussion of the affects of radiant heat on the recorded ambient temperature it was accepted across the participants as a reasonable benchmark for a dangerous temperature over a sustained period of exposure that was applicable across a broad spectrum of user groups.

Some of the key queries/statements that arose from this session are listed below:

Researcher Question:
Do they connect the data to the place / site?
Participant Answer:

> *" Yes, the Rose-Chart for Watt St is particularly effective in connecting the data to the site conditions present on the western side of Watt St - The spatialisation makes the wind patterns clear, with little to no air flow moving through the site, the spike in surface temperature directly correlates. "*

Participant Observation:

"I would like to compare these urban sites and a residential site. Fascinating how these highly pedestrianised spaces are super hot - whats going on in the leafy, sleepy suburbs?"

"This spatialisation and the material surface temperatures indicates there is a major issue with how our city works, and how the way it looks has become a physical danger to users. "

CO-DESIGN:
HUNTER ST SESSION

HUNTER ST MITIGATION MATRIX/KIT OF PARTS CARD GAME

Initial Reactions/Discussions following the Matrix/Kit of Parts Card Game:
The application of the kit of parts as a card game to be played over the top of the Panoramas proved extremely useful and interactive as a prompt for discussions about the application of this research. Working through a best case scenario with unlimited budget, a realistic scenario and a worst case limited budget scenario for each of the three sites the participants combined their expertise with the mitigation techniques on offer and create a series of mitigation strategies. The were also a series of additions to the kit of parts that were absent from the research:

Retaining Existing Trees
Sandstone Seating and Edging
Solar Shade Structures

The above suggestions could be incorporated in the kit of parts section of this report. Some of thekey queries/statements that arose during this session are listed below:

Researcher Question:

Where to Next?
Participant Answer:

> *"Perhaps initially a 'Smart Pole of the Day' could be featured to the public, creating a novelty awareness of site conditions."*
> *"Can interest in this topic among the public take a different angle? Species loss/Animal migration? Perhaps taking an environmental ecology loss angle would appeal to a greater audience."*

The following specific strategies (photographed) emerged from the Hunter St session.
FIGURE 1 - When Worth Place was discussed in the context of having no constraints, the working group identified a combination of strategies that work together, localised in the currently unshaded public hardscape. The strategies identified from the Kit of Parts were: 3.05 Trellis Shade Structure, 5.03 Water Features/fountains, 1.08 Permeable Pavement (traditional), 3.07 Permeable Pavement - Lawn Paver, 1.12 Turf Planted Light Rail Tracks, and 3.03/ 3.01 Shade Tree Planting.

FIGURE 2 - In contrast, when taking into constraints, strategies identified were: Retain Existing Trees, 2.04 Awnings, 2.05 Eave Extensions, 4.04 Smart Irrigation Systems, 5.01 Retrofitting to align with WSUD Principles, 3.02 Kerb Extension Garden Beds with Trees, 3.01 Pedestrian Crossing Shade Tree Planting, and 3.05 Trellis Shade Structure.

FIGURE 3 - As a bare bones option, as a priority, worth place could be improved with 3.05 Trellis Shade Structure, and 3.02 Kerb Extension Garden Beds with Trees.

FIGURE 1. Best case scenario - no financial or planning constraints.

FIGURE 2. Realistic scenario - current financial situation and planning constraints

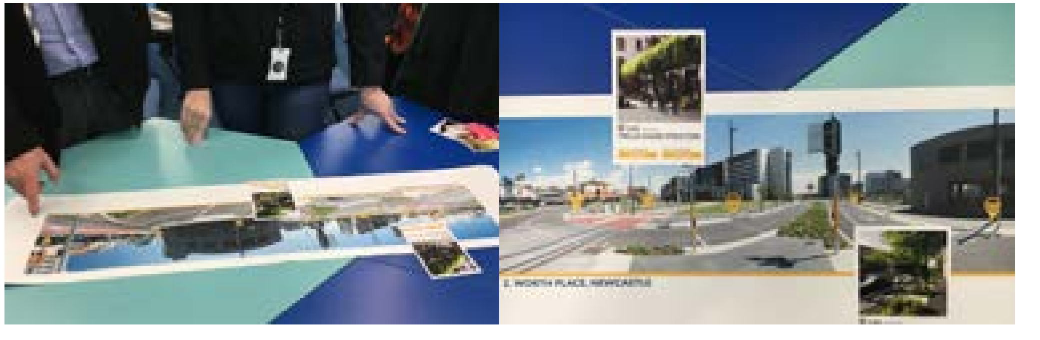


FIGURE 3. Worst case scenario - bare bones finance available

 Hunter St Kit of Parts Card Game Scenarios: Best Case Scenario (TOP), Realistic Scenario (MIDDLE), Worst Case Scenario (Bottom).

CO-DESIGN:
WALLSEND SESSION

WALLSEND INTRODUCTION AND VISUALISATION OF DATA

Initial Reactions/Discussion following Presentation of Visualisation Methods:
The use of the ratio was further analysed, establishing it was a useful tool, however required simplification and focus on a micro scale to become useful. There was discussion around conventionalmethods of recording thermal properties of urban space, such as heat mapping/ thermal imaging andthe military connotations of such methods.
A desire to understand the implications of the temperatures being recorded was raised, and the idea of a strategy focused on a barometer of 'comfort levels' was raised. Audience specific tactics ofcommunication were a concurrent theme across all sessions, and dominated the discussion once again.

Some of the key queries/statements that arose are listed below:

Participant Question:
How can this research be applied to regional centers?

Researcher Question:
Are these visualisations clear?
Participant Answer:
"Scatter graph are clear, they could definitely attach to a live feed of data."

WALLSEND SPATIALISATION OF DATA

Initial Reactions/Discussions following Semi Led Presentation of Spatialisation Material:
The Rose-charts were extremely well received as a design tool - a guide to 'what not to do' in relation to material surface temperatures. As Wallsend has a basic material palette the correlation between high temperatures and large areas of unshaded asphalt become very clear. The feedback on the Panoramas was consistent with the Hunter St session, with a desire for more icons, less text was expressed. An emphasis on graphically expressing the 'danger zone' through a red line/bar chart similar to the rose-charts.

Some of the key queries/statements that arose from this session are listed below:

Participant Observation:
"One of Councils roles in Peak Temperature events is to direct vulnerable people to cooler places. This study indicates danger is present on their journey – This research can inform moving bus stops and incorporating alerts on public transport."

WALLSEND MITIGATION MATRIX/KIT OF PARTS CARD GAME

Initial Reactions/Discussions following Matrix/Kit of Parts Card Game:

Several of the mitigation strategies were flagged as issues in terms of clear view lines and escape routes to ensure the safety of public spaces. Wallsend experiences a greater level of crime than the more urban sites, and therefore issues around obstruction of street lights with trellis structures and enclosed bus stops trapping users were raised. The matrix proved extremely useful and future use was discussed as a tool for public consultation for placemaking projects. The use of maps to convey material was queried, with anecdotes shared of instances where public consultation with maps proved unhelpful, and in one instance misleading.

Some of the key queries/statements that arose during this session are listed below:

Researcher Question:
Where to Next?
Participant Answer:
" I'd like to see the continuation of data leading good decisions and better outcomes, thats the allure of the 'Smart Trees' project."

Researcher Question:
Are these mitigation techniques realistic?
Participant Answer:
"There is a disconnect between the 'sexy' image of a solution and the real life application of the solution. It needs to be applied to the actual site."

CO-DESIGN:
WALLSEND SESSION

WALLSEND MITIGATION MATRIX/KIT OF PARTS CARD GAME

The following specific strategies (photographed) emerged from the Wallsend session:

FIGURE 1 - A best case scenario was envisaged as a combined approach to thinking about, in a largely uncovered carpark typology shading and surface treatments were prioritised.
6.01 Identification of public commoning 2.10 high albedo facades, 2.04 awnings, car park and kerb shade trees, and high emissivity coatings/pavement paining.

FIGURE 2 -The realistic solutions focused on treatment of asphalt through 1.04 light coloured asphalt and 1.06 cool asphalt compound admixtures and kerb extension planting.

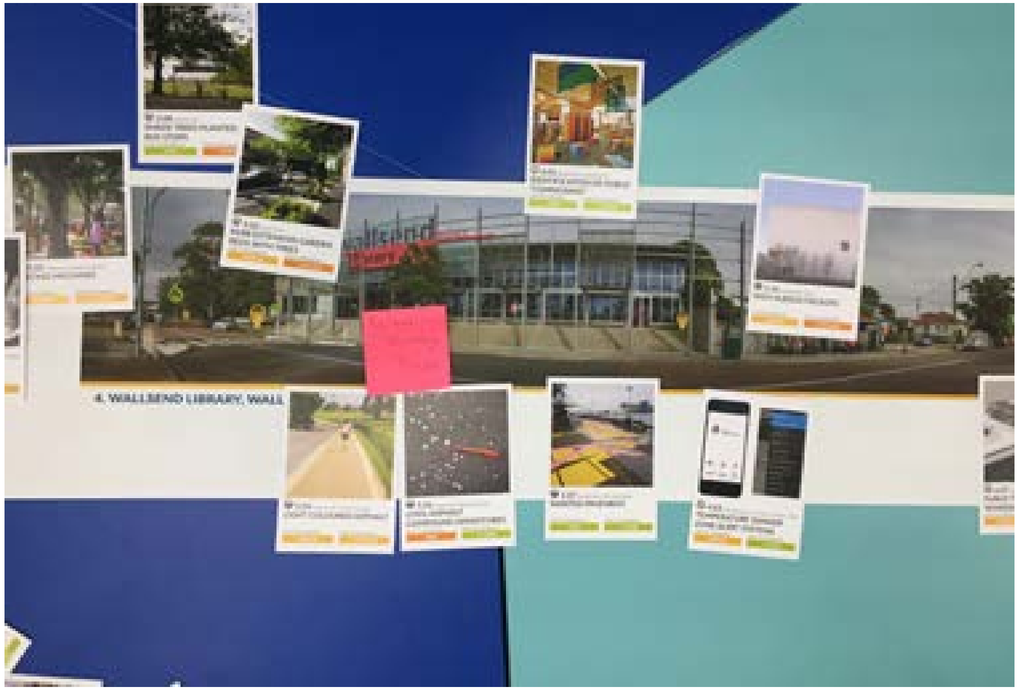


FIGURE 1. Best case scenario focussing on ground plane hardscape treatments and shading

FIGURE 2. Realistic scenario focussing on treatment of hard surfaces.

CO-DESIGN:
BERESFIELD SESSION

BERESIELD INTRODUCTION AND VISUALISATION OF DATA

Initial Reactions/Discussion following Presentation of Visualisation Methods:
The shift in visualisation tactics adopted for the Beresfield site was positively received, seeing the individual materials analysed in sun and shade conditions was seen as an extremely useful exercise. The greater attention paid to the micro details of this site contributed to a greater level of engagement and understanding across all participants.
Some of the key queries/statements that arose are listed below:

Participant Question:

> *"The high temperatures recorded for Mulch is really interesting in terms of root health – is the mulch killing the trees?"*

BERESFIELD SPATIALISATION OF DATA

Initial Reactions/Discussions following Semi Led Presentation of Spatialisation Material:

The Rose-charts in combination with the material visualisations were very positively received. Some confusion arose from the shift from groundscape surface materials to building elevation readings. There was a desire to see a section capturing: interior of building > footpath > kerb > road with material temperatures referenced across this section, capturing the complete image of temperatures experienced through the site.
A general comment across the spatialisations was the absence of information about the broader environmental conditions: prevailing wind patterns, shading etc. There was a suggestion that the smart trees data be layered with more sophisticated broad reaching Bureau of Meteorology data as a future project.

Some of the key queries/statements that arose from this session are listed below:

Participant Observation:

> *"The temperature readings of the wall material palettes is really important, this information could be used as encouragement for business to green/shade/louvers their facades."*

BERESFIELD MITIGATION MATRIX/KIT OF PARTS CARD GAME

Initial Reactions/Discussions following Matrix/Kit of Parts Card Game:

The Kit of Parts card game and Matrix were heavily interrogated and contributed to robust and informative discussions during this session. There was a keen focus on the relationship between time and cost, with some mitigation measures requiring high initial capital costs, but offering low cost maintanence and longevity as a payoff. There was also discussion around combining several of the strategies, such as a shade structure eqiuped with solar panels, generating power and resulting over time with a cost benefit scenario.

Some of the key queries/statements that arose during this session are listed below:

Researcher Question:
Is this information legible and accessible? What other ways can we examine various mitigation approaches?
Participant Answer:
" There is an issue with the kit of parts item listed as 'Permeable Paving' - don't want a mis-naming of material diminishing a very useful part of the WSUD toolkit. Please rename to 'Porous Pavement."

Researcher Question:
Where to Next?
Participant Answer:
" We need to interrogate how the smart poles can do more? Direct you to the shadier path, be the shade? We know that the poles generate heat - can we grow something special with this heat? Can we hack the pole?"

"We could seek out receptive neighbourhoods and trial some prototype mitigation measures."

CO-DESIGN:
BERESFIELD SESSION

BERESFIELD MITIGATION MATRIX/KIT OF PARTS CARD GAME

The following specific strategies (photographed) emerged from the Beresfield session:

FIGURE 1 - A combined approach to thinking about, in a suburban context, how residents and retailers are led by policy. A suggestion was to combine the following strategies:
6.02 Future planing policy combined with 2.03 building orientation, 2.10 high albedo facades, 2.04 awnings, private vegetation growth

The realistic solutions main were about investments into hardscape infrastructure (Figure 2), however they recognised implications on contracts, equipment and training.

The idea of incorporating place making activities, (e.g., public mural) as part of the solution was raised - utilising a high emissivity coating/ painted pavement.

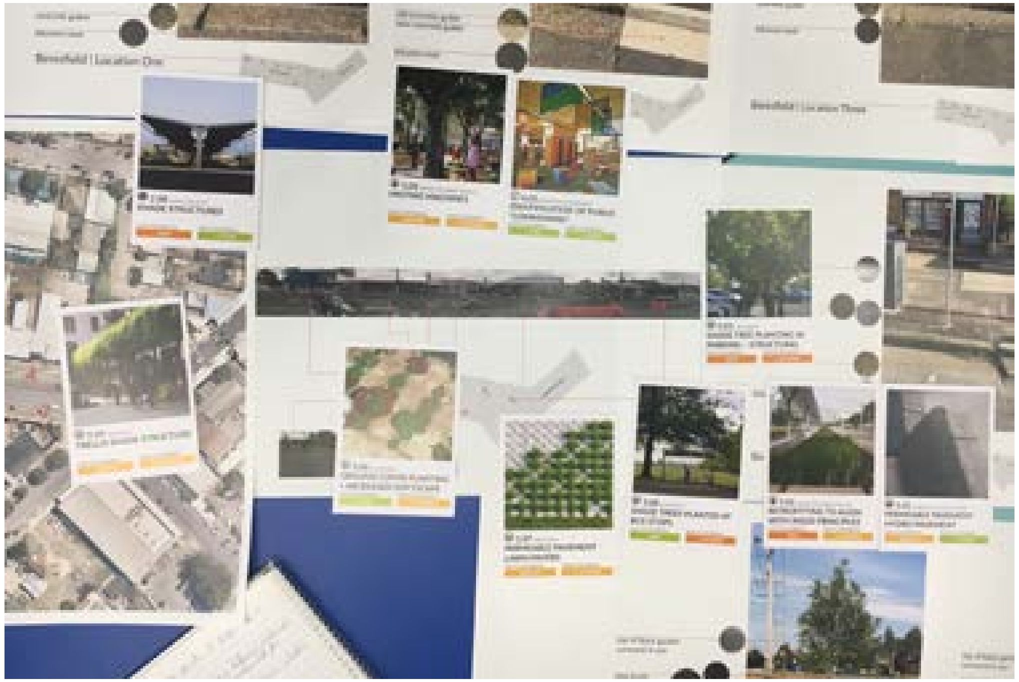


FIGURE 1. Best case scenario focussing on planning policy and surrounding building treatment.

FIGURE 2. Realistic scenario focussing on treatment of hard surfaces.

SECTION 05.

CONLUSION/ RECOMMENDATIONS

Conclusions 5.0

CONCLUSIONS + REOMMENDATIONS

This final section fo the report will collate the feedback from the Co-design workshop and offer a series of amendments to the visualisations and spatialisations developed by the research team for effective future use. We will then make a series of recommendations for future action based on the results of the data collected and the severity of the UHIE detected in Newcastle across all five sites.

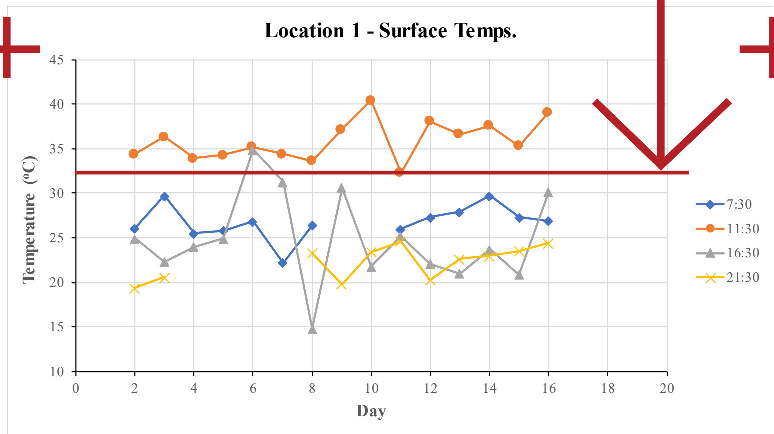
VISUALISATION

Future iterations of this type of project, whereupon thermal data must be conveyed to a broad audience might adapt the following recommendations:

Reduce data to the most simple reduction possible - ensure narrative and pair all necessary information into a single image - see diagram below.

Combine Mapping and Photograph of site conditions with data to ensure audience connects site conditions with data represented.

Mark 'Danger Zone/Above Comfort Level' temperature on graphs to indicate when surface temperatures exceed normal levels.



CONCLUSIONS + REOMMENDATIONS: ROSE-CHART

DATA SPATIALISATION: Rose-Chart

In addition to utilising multiple images with visualisation techniques (as demonstrated on the previous page), juxtaposing the rose-charts with the in-situ site material photographs and the data collection points plan would help to locate the viewer within the site and its material palette as well as allow for a deeper understanding of the material performance. Please see images below.

Data log location map with call out to specific site corresponding with Rose-Chart

Site photograph and material callouts for each data log location.

Rose-Chart with danger zone temperature threashold at 32 degrees emphasised.

+

+

Recommended compilation of information for future communication of data:
Map/location diagram (LHS), Data graph (CENTRE), Image/location key (RHS)

CONCLUSIONS + REOMMENDATIONS: PANORAMA

DATA SPATIALISATION: Rose-Chart

A multi-image approach could also be utilised for the panorama data sets. In addition to the panoramas with the icons, a plan or aerial photo of each data point directly beneath the panorama as well as the specific data point photos (see images following page) could assist viewers with the spatial locations of the data points, their contexts, and their materiality. Additionally, updating the numeric data regarding the temperatures with a colour coding (green- within acceptable ranges, yellow- approaching heat stress, red- avoid area due to significant heat) could assist with key messaging of more pressing sites within each study site.

Panorama with simplified data and temperature thresholds.

Data log location map with call out to specific site corresponding with panorama.

Data log locations images detailing exact point of survey.

CONCLUSIONS + REOMMENDATIONS: MATRIX AND CO-DESIGN

MATRIX AND KIT OF PARTS

Although this part of the co-design workshop across the three sites was the most successful in terms of participation and ideation regarding mitigating UHIE, it could be expanded to include a range of community-based priorities. For example, as key neighbourhood centres are being redeveloped, cross programming street scape amenities and public realm upgrades with UHIE mitigation measures / techniques might lead to unique-place based inventions. The key to getting greater public buy-in would be to hold co-design workshops with key community stakeholders to understand their priorities as well as to narrate and engage them with issues of UHIE. Additionally, placemaking pilot projects where selected ideas from the Kit of Parts are tested with local community residents, before, during and after installation might lead to further innovation. It's important to continue to hold spaces within the matrix open, for new ideas to emerge as well as new products and technologies. It is reasonable to suggest that combating UHIE will always need a combination of measures, strategies, and interventions which are site specific and which evolve over time. It became most evident through this part of the research and during the co-design workshops that UHIE is a complex challenge which necessitates a multi-valent approach to its mitigation.

REFLECTIONS OVERALL

- At the end of the Co-Design Workshops the research team posited the following questions:
- How can this research project inform not only data collection and data visualisation but amelioration via the SMART Pole technologies?
- Where to next?
- Significantly, the research team and NCC workshop participants were keen to explore other opportunities for collaboration. These include but are not limited to:
- Pilots or trials where the smart poles after sensing UHIE conditions become site specific misting structures or vine structures.
- Pilots where the heat harvested from the smart poles might produce energy for a cooling fan or create a different micro-climatic environment for epiphytes. An epiphyte is a plant that grows on the surface of a plant and derives its moisture and nutrients from the air, rain, water or from debris accumulating around it. Epiphytes take part in nutrient cycles and add to both the diversity and biomass of the ecosystem in which they occur, like any other organism.
- As a number of opportunities may present themselves through local neighbourhood redevelopment works, the research team is keen to collaborate in place making or other activation projects using the kit of parts, where UHIE can be a useful means to alter spaces in an informed way. The research team were key to work in sights such as Beresfield or Wallsend where communities were described as particularly vulnerable.

SECTION 06.

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SECTION 07.

APPENDIX

APPENDIX A: Financial Report

Prepared by Kristie Golledge, Administration Officer Research and Innovation, The University of Newcastle.

Smart Moves Project 10.32737		
SueAnne Ware		
School of Architecture & Design - FEBE		
Allocated Budget	**$**	**85,000.00**
2018 Expenditure	**$**	**18,919.00**
Professional Services	**$**	**15,000.00**
17/12 Design Anthology	*$*	*3,863.64*
11/12 Design Anthology	*$*	*2,681.82*
12/12 Design Anthology	*$*	*4,045.45*
17/12 Design Anthology	*$*	*4,409.09*
Academic Salaries	**$**	**3,656.00**
Dr Timothy Burke - AA.01	*$*	*3,656.00*
Casual Administrative Salaries	**$**	**263.00**
Jedda Cranfield - HEW01.01	*$*	*263.00*
2019 Expenditure	**$**	**64,531.62**
Workshop and Materials	**$**	**313.37**
11/03 Jaycar Electronics	*$*	*240.73*
11/03 Jycar Electronics	*$*	*72.64*
Utilities (Phone)	**$**	**95.25**
01/04 Mobile / IPAD Charges Q1	*$*	*95.25*
Ongoing Academic Salaries	**$**	**12,615.00**
Dr Timothy Burke - AA.01	*$*	*12,615.00*
Ongoing Administrative Salaries	**$**	**18,500.00**
D'Arcy Newberry Dupe - HEW03.01	*$*	*18,500.00*
Casual Administrative Salaries	**$**	**33,008.00**
Jedda Cranfield - HEW01.01	*$*	*4,055.00*
Charlie Dibley - HEW01.01	*$*	*5,197.00*
Georgia Kissa (PhD candidate) - HEW05.01	*$*	*12,106.00*
Walter Rowlands - HEW01.01	*$*	*6,532.00*
Hannah Cheetham - HEW01.01	*$*	*5,118.00*
Total Allocated Budget	**$**	**85,000.00**
Total Expenditure	**$**	**84,573.61**
Remaining Allocated Budget	$	426.39
Unallocatted Transactions (Recent expendtitures for Co-Design Workshop which have yet to clear the system)	**$**	**1,122.99**
AT Newcastle Print Service	*$*	*42.73*
UON Print Centre	*$*	*14.55*
Officeworks	*$*	*190.91*
Kent Rowe Digital Print	*$*	*87.27*
Kent Rowe Digital Print	*$*	*87.27*
Kent Rowe Digital Print	*$*	*87.27*
Kent Rowe Digital Print	*$*	*87.27*
Blue Door Restaurant	*$*	*97.27*
Fast Fuel Food Pty Ltd	*$*	*14.64*
Fast Fuel Food Pty Ltd	*$*	*16.82*
Pipntoobs Pty Ltd	*$*	*37.73*
The Heights Catering Company Pty Ltd	*$*	*359.26*

APPENDIX B: Temperature Data ALL SITES

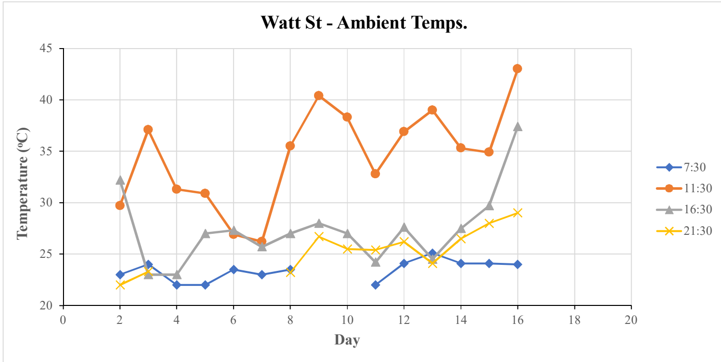
Complete set of Data collected from the five sites over the 12-16 day study period.

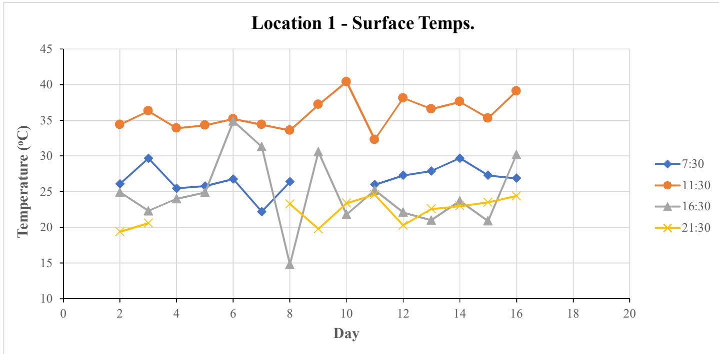
Research Collated by UoN Students: Hannah Cheetham, Walter Rowlands, Charlie Dibley and Jedidiah Cranfield

Site 1 – Watt Street

SCROLL FOR ALL SITES →

LOCATION 1 (Grass)





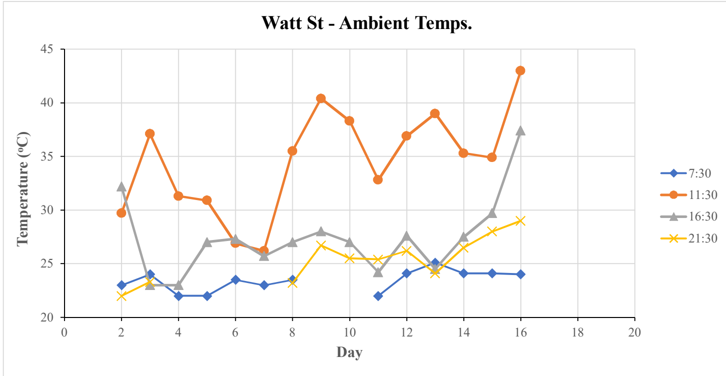
Ambient	
Time	Average Temp. (°C)
7:30:00	23.4
11:30:00	34.5
16:30:00	27.4
21:30:00	25.4

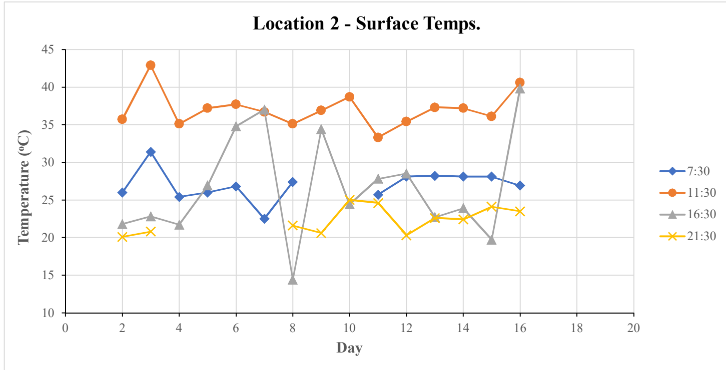
Surface	
Time	Average Temp. (°C)
7:30:00	26.7
11:30:00	35.9
16:30:00	24.8
21:30:00	22.3

Ambient (All of Watt St Sites)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	23.0	29.7	32.2	22.0
Jan-09	3	30, 22	24.0	37.1	23.0	23.3
Jan-10	4	27, 21	22.0	31.3	23.0	
Jan-11	5	26, 19	22.0	30.9	27.0	
Jan-12	6	33, 20	23.5	26.9	27.3	
Jan-13	7	31, 21	23.0	26.2	25.7	
Jan-14	8	29, 20	23.5	35.5	27.0	23.2
Jan-15	9	34, 21		40.4	28.0	26.7
Jan-16	10	35, 22		38.3	27.0	25.5
Jan-21	11	29, 21	22.0	32.8	24.2	25.4
Jan-22	12	33, 22	24.1	36.9	27.6	26.2
Jan-23	13	32, 22	25.1	39.0	24.5	24.1
Jan-29	14	33, 22	24.1	35.3	27.5	26.5
Jan-30	15	34, 23	24.1	34.9	29.7	28.0
Jan-31	16	37, 21	24.0	43.0	37.4	29.0
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			23.4	34.5	27.4	25.4

Surface (Location 1)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	26.1	34.4	24.9	19.4
Jan-09	3	30, 22	29.7	36.3	22.3	20.6
Jan-10	4	27, 21	25.5	33.9	24.0	
Jan-11	5	26, 19	25.8	34.3	24.9	
Jan-12	6	33, 20	26.8	35.2	34.9	
Jan-13	7	31, 21	22.2	34.4	31.3	
Jan-14	8	29, 20	26.4	33.6	14.8	23.3
Jan-15	9	34, 21		37.2	30.6	19.8
Jan-16	10	35, 22		40.4	21.8	23.4
Jan-21	11	29, 21	26.0	32.3	25.2	24.6
Jan-22	12	33, 22	27.3	38.1	22.1	20.3
Jan-23	13	32, 22	27.9	36.6	21.0	22.6
Jan-29	14	33, 22	29.7	37.6	23.7	23.0
Jan-30	15	34, 23	27.3	35.3	20.9	23.5
Jan-31	16	37, 21	26.9	39.1	30.2	24.4
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			26.7	35.9	24.8	22.3

LOCATION 2 (Grass)





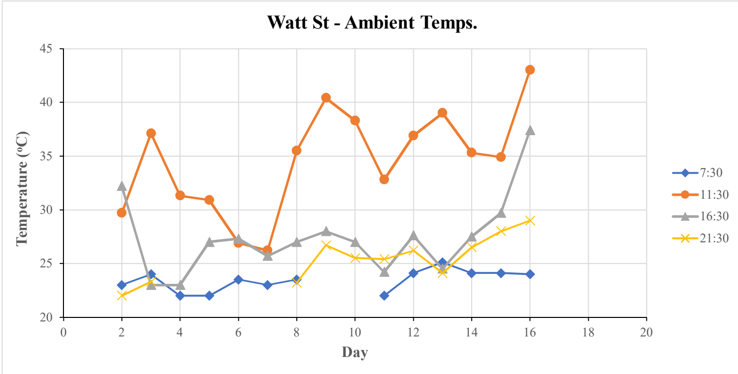
Ambient	
Time	Average Temp. (°C)
7:30:00	23.4
11:30:00	34.5
16:30:00	27.4
21:30:00	25.4

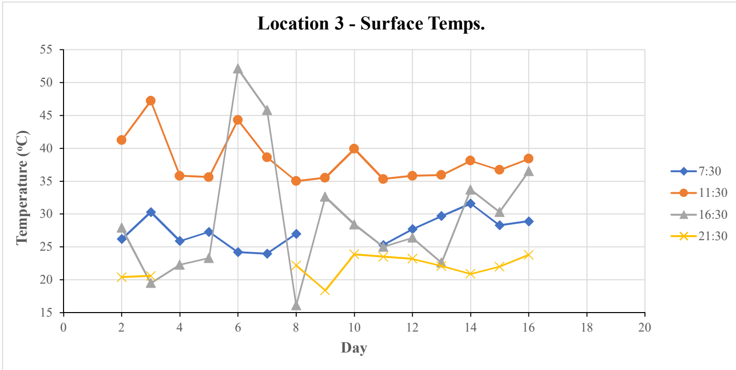
Surface	
Time	Average Temp. (°C)
7:30:00	27.0
11:30:00	37.1
16:30:00	26.7
21:30:00	22.3

Ambient (All of Watt St Sites)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	23.0	29.7	32.2	22.0
Jan-09	3	30, 22	24.0	37.1	23.0	23.3
Jan-10	4	27, 21	22.0	31.3	23.0	
Jan-11	5	26, 19	22.0	30.9	27.0	
Jan-12	6	33, 20	23.5	26.9	27.3	
Jan-13	7	31, 21	23.0	26.2	25.7	
Jan-14	8	29, 20	23.5	35.5	27.0	23.2
Jan-15	9	34, 21		40.4	28.0	26.7
Jan-16	10	35, 22		38.3	27.0	25.5
Jan-21	11	29, 21	22.0	32.8	24.2	25.4
Jan-22	12	33, 22	24.1	36.9	27.6	26.2
Jan-23	13	32, 22	25.1	39.0	24.5	24.1
Jan-29	14	33, 22	24.1	35.3	27.5	26.5
Jan-30	15	34, 23	24.1	34.9	29.7	28.0
Jan-31	16	37, 21	24.0	43.0	37.4	29.0
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			23.4	34.5	27.4	25.4

Surface (Location 2)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	26.0	35.7	21.8	20.1
Jan-09	3	30, 22	31.4	42.9	22.8	20.8
Jan-10	4	27, 21	25.4	35.1	21.7	
Jan-11	5	26, 19	26.0	37.2	26.9	
Jan-12	6	33, 20	26.8	37.7	34.8	
Jan-13	7	31, 21	22.5	36.7	37.0	
Jan-14	8	29, 20	27.4	35.1	14.4	21.6
Jan-15	9	34, 21		36.9	34.4	20.6
Jan-16	10	35, 22		38.7	24.4	25.0
Jan-21	11	29, 21	25.7	33.3	27.8	24.6
Jan-22	12	33, 22	28.1	35.4	28.5	20.3
Jan-23	13	32, 22	28.2	37.3	22.7	22.6
Jan-29	14	33, 22	28.1	37.2	23.9	22.4
Jan-30	15	34, 23	28.1	36.1	19.7	24.1
Jan-31	16	37, 21	26.9	40.6	39.8	23.5
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			27.0	37.1	26.7	22.3

LOCATION 3 (Grass)





Ambient	
Time	Average Temp. (°C)
7:30:00	23.4
11:30:00	34.5
16:30:00	27.4
21:30:00	25.4

Surface	
Time	Average Temp. (°C)
7:30:00	27.4
11:30:00	38.2
16:30:00	29.5
21:30:00	21.9

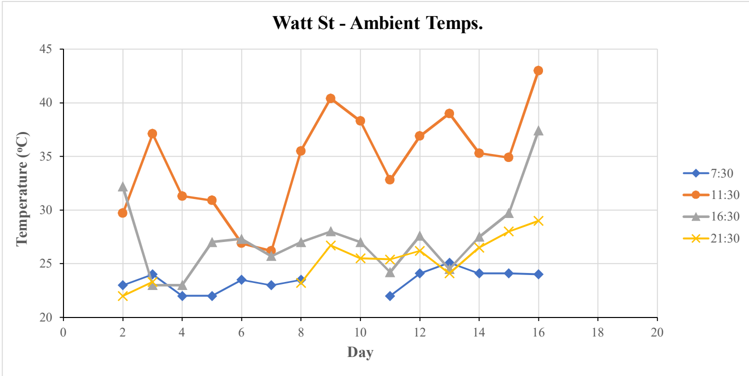
Ambient (All of Watt St Sites)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	23.0	29.7	32.2	22.0
Jan-09	3	30, 22	24.0	37.1	23.0	23.3
Jan-10	4	27, 21	22.0	31.3	23.0	
Jan-11	5	26, 19	22.0	30.9	27.0	
Jan-12	6	33, 20	23.5	26.9	27.3	
Jan-13	7	31, 21	23.0	26.2	25.7	
Jan-14	8	29, 20	23.5	35.5	27.0	23.2
Jan-15	9	34, 21		40.4	28.0	26.7
Jan-16	10	35, 22		38.3	27.0	25.5
Jan-21	11	29, 21	22.0	32.8	24.2	25.4
Jan-22	12	33, 22	24.1	36.9	27.6	26.2
Jan-23	13	32, 22	25.1	39.0	24.5	24.1
Jan-29	14	33, 22	24.1	35.3	27.5	26.5
Jan-30	15	34, 23	24.1	34.9	29.7	28.0
Jan-31	16	37, 21	24.0	43.0	37.4	29.0
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			23.4	34.5	27.4	25.4

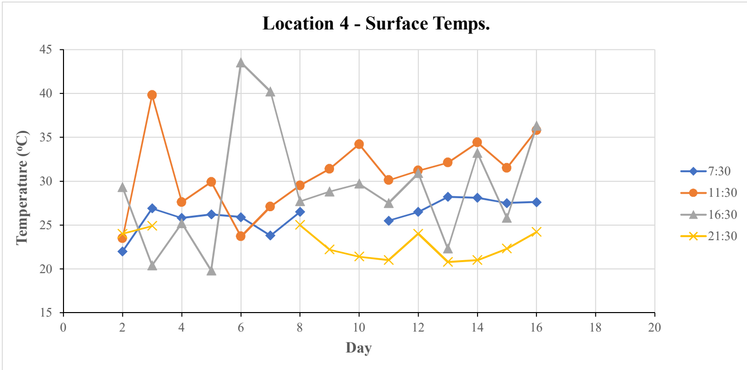
Surface (Location 3)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	26.2	41.2	27.9	20.4
Jan-09	3	30, 22	30.3	47.2	19.5	20.6
Jan-10	4	27, 21	25.9	35.8	22.3	
Jan-11	5	26, 19	27.3	35.6	23.3	
Jan-12	6	33, 20	24.2	44.3	52.1	
Jan-13	7	31, 21	24.0	38.6	45.8	
Jan-14	8	29, 20	27.0	35.0	16.1	22.2
Jan-15	9	34, 21		35.5	32.6	18.4
Jan-16	10	35, 22		39.9	28.4	23.9
Jan-21	11	29, 21	25.3	35.3	25.0	23.5
Jan-22	12	33, 22	27.7	35.8	26.4	23.2
Jan-23	13	32, 22	29.7	35.9	22.6	22.1
Jan-29	14	33, 22	31.6	38.1	33.7	20.9
Jan-30	15	34, 23	28.3	36.7	30.3	22.0
Jan-31	16	37, 21	28.9	38.4	36.5	23.8
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			27.4	38.2	29.5	21.9

LOCATION 4 (Pebblecrete)



Ambient	
Time	Average Temp. (°C)
7:30:00	23.4
11:30:00	34.5
16:30:00	27.4
21:30:00	25.4



Surface	
Time	Average Temp. (°C)
7:30:00	26.2
11:30:00	30.8
16:30:00	29.4
21:30:00	22.8

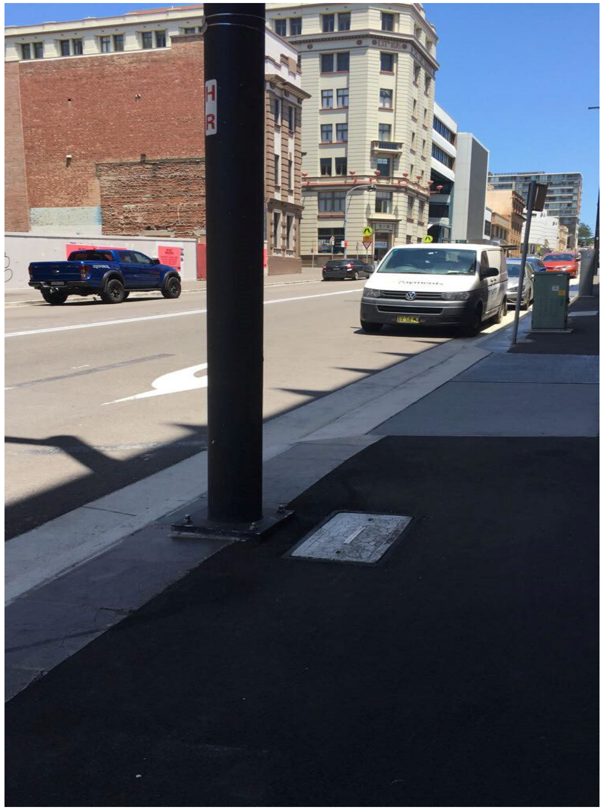
Ambient (All of Watt St Sites)

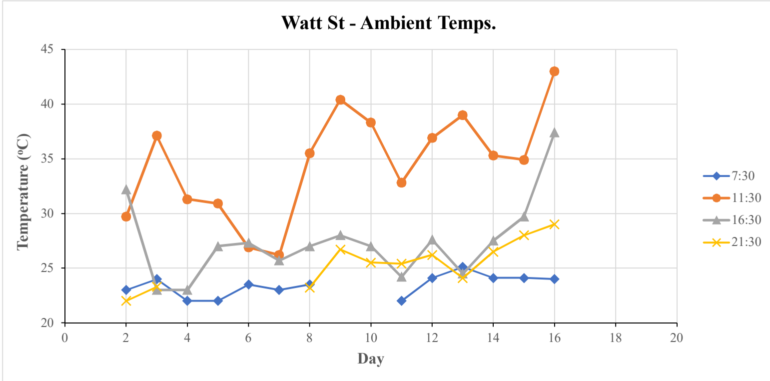
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	23.0	29.7	32.2	22.0
Jan-09	3	30, 22	24.0	37.1	23.0	23.3
Jan-10	4	27, 21	22.0	31.3	23.0	
Jan-11	5	26, 19	22.0	30.9	27.0	
Jan-12	6	33, 20	23.5	26.9	27.3	
Jan-13	7	31, 21	23.0	26.2	25.7	
Jan-14	8	29, 20	23.5	35.5	27.0	23.2
Jan-15	9	34, 21		40.4	28.0	26.7
Jan-16	10	35, 22		38.3	27.0	25.5
Jan-21	11	29, 21	22.0	32.8	24.2	25.4
Jan-22	12	33, 22	24.1	36.9	27.6	26.2
Jan-23	13	32, 22	25.1	39.0	24.5	24.1
Jan-29	14	33, 22	24.1	35.3	27.5	26.5
Jan-30	15	34, 23	24.1	34.9	29.7	28.0
Jan-31	16	37, 21	24.0	43.0	37.4	29.0
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			23.4	34.5	27.4	25.4

Surface (Location 4)

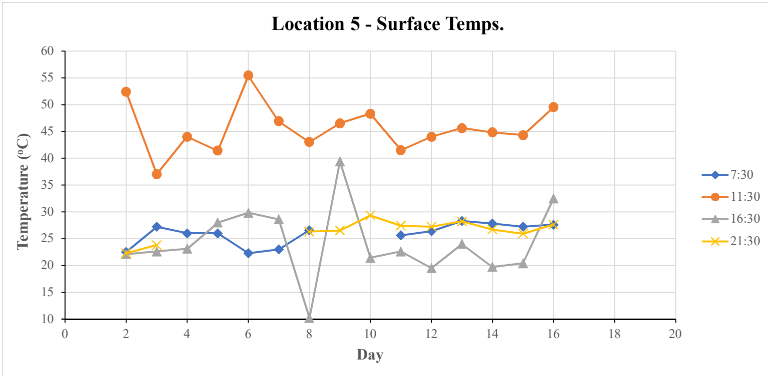
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	22.0	23.5	29.3	24.0
Jan-09	3	30, 22	26.9	39.8	20.4	24.9
Jan-10	4	27, 21	25.8	27.6	25.2	
Jan-11	5	26, 19	26.2	29.9	19.8	
Jan-12	6	33, 20	25.9	23.7	43.5	
Jan-13	7	31, 21	23.8	27.1	40.2	
Jan-14	8	29, 20	26.5	29.5	27.7	25.0
Jan-15	9	34, 21		31.4	28.8	22.2
Jan-16	10	35, 22		34.2	29.7	21.4
Jan-21	11	29, 21	25.5	30.1	27.5	21.0
Jan-22	12	33, 22	26.5	31.2	30.9	24.0
Jan-23	13	32, 22	28.2	32.1	22.3	20.8
Jan-29	14	33, 22	28.1	34.4	33.2	21.0
Jan-30	15	34, 23	27.5	31.5	25.8	22.3
Jan-31	16	37, 21	27.6	35.8	36.3	24.2
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			26.2	30.8	29.4	22.8

LOCATION 5 (Asphalt)





Ambient	
Time	Average Temp. (°C)
7:30:00	23.4
11:30:00	34.5
16:30:00	27.4
21:30:00	25.4



Surface	
Time	Average Temp. (°C)
7:30:00	25.9
11:30:00	45.6
16:30:00	24.3
21:30:00	26.5

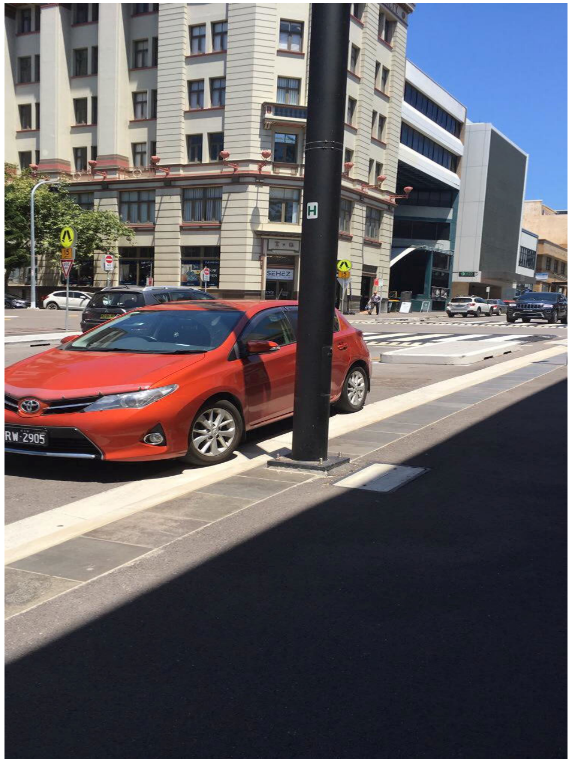
Ambient (All of Watt St Sites)

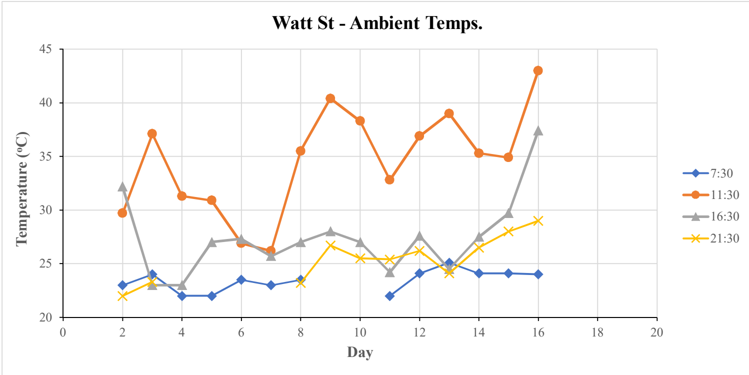
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	23.0	29.7	32.2	22.0
Jan-09	3	30, 22	24.0	37.1	23.0	23.3
Jan-10	4	27, 21	22.0	31.3	23.0	
Jan-11	5	26, 19	22.0	30.9	27.0	
Jan-12	6	33, 20	23.5	26.9	27.3	
Jan-13	7	31, 21	23.0	26.2	25.7	
Jan-14	8	29, 20	23.5	35.5	27.0	23.2
Jan-15	9	34, 21		40.4	28.0	26.7
Jan-16	10	35, 22		38.3	27.0	25.5
Jan-21	11	29, 21	22.0	32.8	24.2	25.4
Jan-22	12	33, 22	24.1	36.9	27.6	26.2
Jan-23	13	32, 22	25.1	39.0	24.5	24.1
Jan-29	14	33, 22	24.1	35.3	27.5	26.5
Jan-30	15	34, 23	24.1	34.9	29.7	28.0
Jan-31	16	37, 21	24.0	43.0	37.4	29.0
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			23.4	34.5	27.4	25.4

Surface (Location 5)

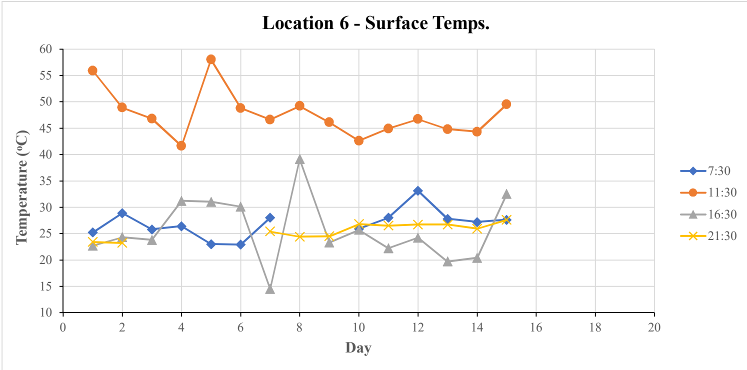
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	22.5	52.4	22.1	22.3
Jan-09	3	30, 22	27.2	37.0	22.6	23.8
Jan-10	4	27, 21	26.0	44.0	23.1	
Jan-11	5	26, 19	26.0	41.4	28.0	
Jan-12	6	33, 20	22.3	55.4	29.8	
Jan-13	7	31, 21	23.0	46.9	28.6	
Jan-14	8	29, 20	26.6	43.0	10.2	26.3
Jan-15	9	34, 21		46.5	39.4	26.5
Jan-16	10	35, 22		48.3	21.4	29.3
Jan-21	11	29, 21	25.6	41.5	22.6	27.4
Jan-22	12	33, 22	26.4	44.0	19.5	27.2
Jan-23	13	32, 22	28.3	45.6	24.0	28.2
Jan-29	14	33, 22	27.8	44.8	19.7	26.7
Jan-30	15	34, 23	27.2	44.3	20.4	25.9
Jan-31	16	37, 21	27.6	49.5	32.5	27.6
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			25.9	45.6	24.3	26.5

LOCATION 6 (Asphalt)





Ambient	
Time	Average Temp. (°C)
7:30:00	23.4
11:30:00	34.5
16:30:00	27.4
21:30:00	25.4



Surface	
Time	Average Temp. (°C)
7:30:00	26.9
11:30:00	47.6
16:30:00	25.6
21:30:00	25.6

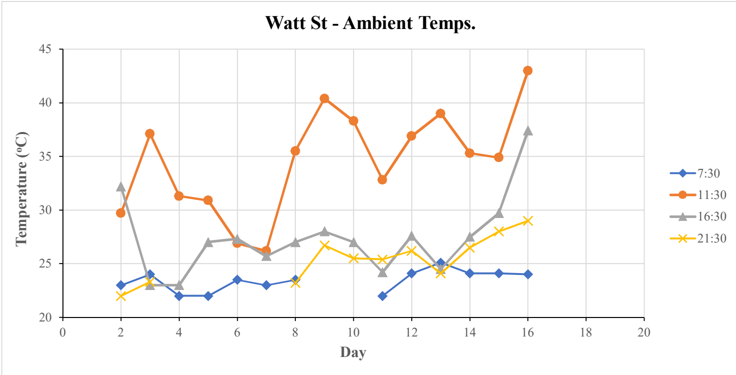
Ambient (All of Watt St Sites)

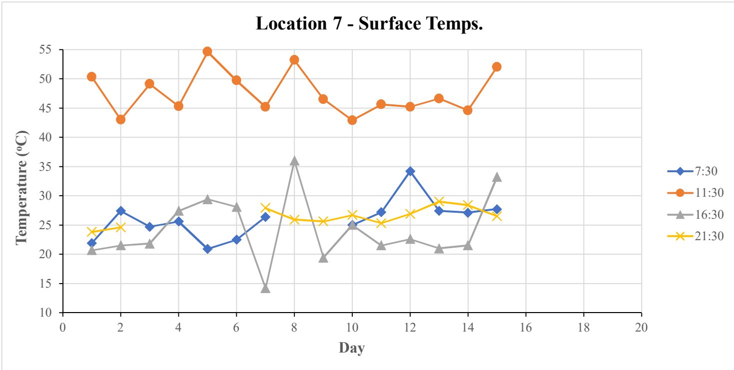
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	23.0	29.7	32.2	22.0
Jan-09	3	30, 22	24.0	37.1	23.0	23.3
Jan-10	4	27, 21	22.0	31.3	23.0	
Jan-11	5	26, 19	22.0	30.9	27.0	
Jan-12	6	33, 20	23.5	26.9	27.3	
Jan-13	7	31, 21	23.0	26.2	25.7	
Jan-14	8	29, 20	23.5	35.5	27.0	23.2
Jan-15	9	34, 21		40.4	28.0	26.7
Jan-16	10	35, 22		38.3	27.0	25.5
Jan-21	11	29, 21	22.0	32.8	24.2	25.4
Jan-22	12	33, 22	24.1	36.9	27.6	26.2
Jan-23	13	32, 22	25.1	39.0	24.5	24.1
Jan-29	14	33, 22	24.1	35.3	27.5	26.5
Jan-30	15	34, 23	24.1	34.9	29.7	28.0
Jan-31	16	37, 21	24.0	43.0	37.4	29.0
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			23.4	34.5	27.4	25.4

Surface (Location 6)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	25.2	55.9	22.7	23.4
Jan-09	3	30, 22	28.9	48.9	24.3	23.2
Jan-10	4	27, 21	25.8	46.8	23.8	
Jan-11	5	26, 19	26.4	41.6	31.2	
Jan-12	6	33, 20	23.0	58.0	31.0	
Jan-13	7	31, 21	22.9	48.8	30.1	
Jan-14	8	29, 20	28.0	46.6	14.5	25.4
Jan-15	9	34, 21		49.2	39.1	24.4
Jan-16	10	35, 22		46.1	23.3	24.5
Jan-21	11	29, 21	25.9	42.6	25.7	26.8
Jan-22	12	33, 22	28.0	44.9	22.2	26.5
Jan-23	13	32, 22	33.1	46.7	24.2	26.7
Jan-29	14	33, 22	27.8	44.8	19.7	26.7
Jan-30	15	34, 23	27.2	44.3	20.4	25.9
Jan-31	16	37, 21	27.6	49.5	32.5	27.6
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			26.9	47.6	25.6	25.6

LOCATION 7 (Asphalt)





Ambient	
Time	Average Temp. (°C)
7:30:00	23.4
11:30:00	34.5
16:30:00	27.4
21:30:00	25.4

Surface	
Time	Average Temp. (°C)
7:30:00	26.0
11:30:00	47.6
16:30:00	24.2
21:30:00	26.4

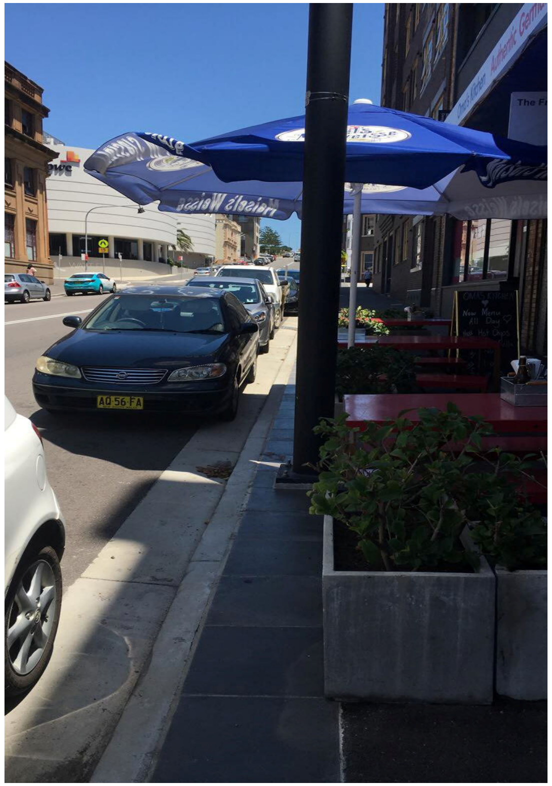
Ambient (All of Watt St Sites)

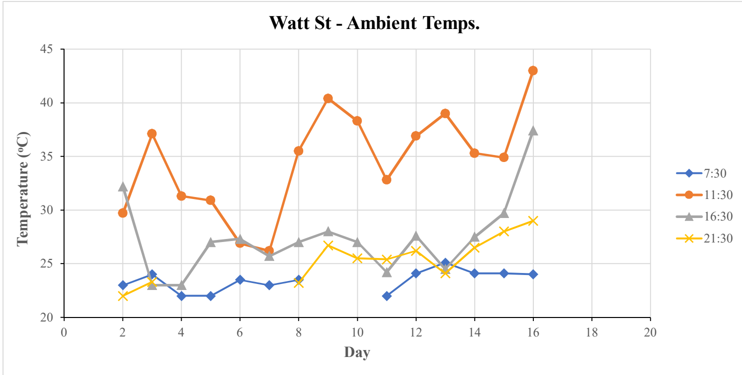
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	23.0	29.7	32.2	22.0
Jan-09	3	30, 22	24.0	37.1	23.0	23.3
Jan-10	4	27, 21	22.0	31.3	23.0	
Jan-11	5	26, 19	22.0	30.9	27.0	
Jan-12	6	33, 20	23.5	26.9	27.3	
Jan-13	7	31, 21	23.0	26.2	25.7	
Jan-14	8	29, 20	23.5	35.5	27.0	23.2
Jan-15	9	34, 21		40.4	28.0	26.7
Jan-16	10	35, 22		38.3	27.0	25.5
Jan-21	11	29, 21	22.0	32.8	24.2	25.4
Jan-22	12	33, 22	24.1	36.9	27.6	26.2
Jan-23	13	32, 22	25.1	39.0	24.5	24.1
Jan-29	14	33, 22	24.1	35.3	27.5	26.5
Jan-30	15	34, 23	24.1	34.9	29.7	28.0
Jan-31	16	37, 21	24.0	43.0	37.4	29.0
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			23.4	34.5	27.4	25.4

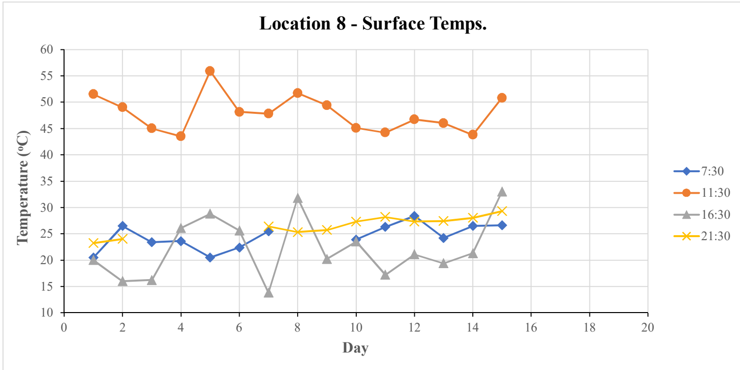
Surface (Location 7)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	21.9	50.3	20.7	23.8
Jan-09	3	30, 22	27.4	43.0	21.5	24.6
Jan-10	4	27, 21	24.7	49.1	21.8	
Jan-11	5	26, 19	25.6	45.3	27.4	
Jan-12	6	33, 20	20.9	54.6	29.4	
Jan-13	7	31, 21	22.5	49.7	28.1	
Jan-14	8	29, 20	26.4	45.2	14.2	27.9
Jan-15	9	34, 21		53.2	36.0	25.9
Jan-16	10	35, 22		46.5	19.4	25.6
Jan-21	11	29, 21	25.0	42.9	25.0	26.7
Jan-22	12	33, 22	27.2	45.6	21.5	25.3
Jan-23	13	32, 22	34.2	45.2	22.6	26.9
Jan-29	14	33, 22	27.4	46.6	21.0	29.0
Jan-30	15	34, 23	27.1	44.6	21.5	28.4
Jan-31	16	37, 21	27.7	52.0	33.2	26.5
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			26.0	47.6	24.2	26.4

LOCATION 8 (Asphalt)







Ambient	
Time	Average Temp. (°C)
7:30:00	23.4
11:30:00	34.5
16:30:00	27.4
21:30:00	25.4

Surface	
Time	Average Temp. (°C)
7:30:00	24.5
11:30:00	47.9
16:30:00	22.3
21:30:00	26.6

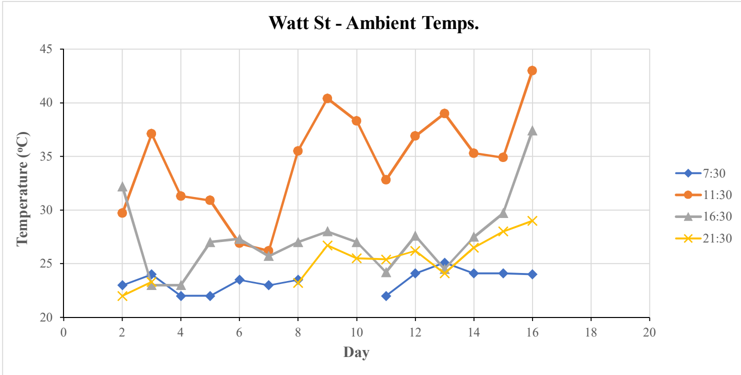
Ambient (All of Watt St Sites)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	23.0	29.7	32.2	22.0
Jan-09	3	30, 22	24.0	37.1	23.0	23.3
Jan-10	4	27, 21	22.0	31.3	23.0	
Jan-11	5	26, 19	22.0	30.9	27.0	
Jan-12	6	33, 20	23.5	26.9	27.3	
Jan-13	7	31, 21	23.0	26.2	25.7	
Jan-14	8	29, 20	23.5	35.5	27.0	23.2
Jan-15	9	34, 21		40.4	28.0	26.7
Jan-16	10	35, 22		38.3	27.0	25.5
Jan-21	11	29, 21	22.0	32.8	24.2	25.4
Jan-22	12	33, 22	24.1	36.9	27.6	26.2
Jan-23	13	32, 22	25.1	39.0	24.5	24.1
Jan-29	14	33, 22	24.1	35.3	27.5	26.5
Jan-30	15	34, 23	24.1	34.9	29.7	28.0
Jan-31	16	37, 21	24.0	43.0	37.4	29.0
Feb-04	17					
Feb-05	18	Data Collection Concluded				
Feb-06	19					
Average Temp. (°C)			23.4	34.5	27.4	25.4

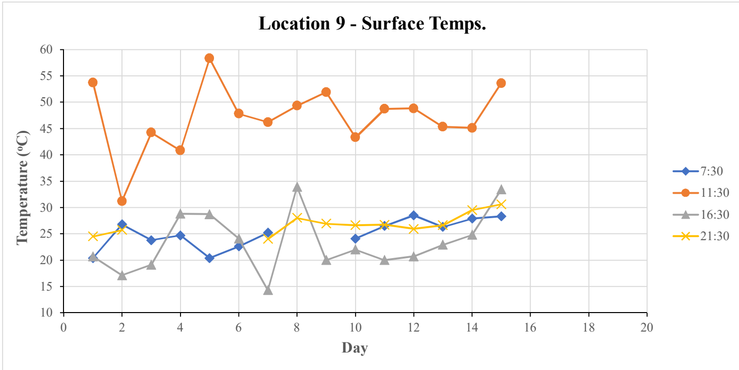
Surface (Location 8)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	20.5	51.5	20.0	23.2
Jan-09	3	30, 22	26.5	49.0	16.0	24.0
Jan-10	4	27, 21	23.4	45.0	16.2	
Jan-11	5	26, 19	23.6	43.5	26.1	
Jan-12	6	33, 20	20.5	55.9	28.8	
Jan-13	7	31, 21	22.4	48.1	25.6	
Jan-14	8	29, 20	25.5	47.8	13.8	26.4
Jan-15	9	34, 21		51.7	31.8	25.3
Jan-16	10	35, 22		49.4	20.2	25.7
Jan-21	11	29, 21	23.9	45.1	23.5	27.3
Jan-22	12	33, 22	26.3	44.2	17.2	28.2
Jan-23	13	32, 22	28.4	46.7	21.1	27.3
Jan-29	14	33, 22	24.2	46.0	19.4	27.4
Jan-30	15	34, 23	26.5	43.8	21.3	28.0
Jan-31	16	37, 21	26.6	50.8	33.0	29.3
Feb-04	17					
Feb-05	18	Data Collection Concluded				
Feb-06	19					
Average Temp. (°C)			24.5	47.9	22.3	26.6

LOCATION 9 (Asphalt)



Ambient	
Time	Average Temp. (°C)
7:30:00	23.4
11:30:00	34.5
16:30:00	27.4
21:30:00	25.4



Surface	
Time	Average Temp. (°C)
7:30:00	25.0
11:30:00	47.2
16:30:00	23.4
21:30:00	26.8

Ambient (All of Watt St Sites)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	23.0	29.7	32.2	22.0
Jan-09	3	30, 22	24.0	37.1	23.0	23.3
Jan-10	4	27, 21	22.0	31.3	23.0	
Jan-11	5	26, 19	22.0	30.9	27.0	
Jan-12	6	33, 20	23.5	26.9	27.3	
Jan-13	7	31, 21	23.0	26.2	25.7	
Jan-14	8	29, 20	23.5	35.5	27.0	23.2
Jan-15	9	34, 21		40.4	28.0	26.7
Jan-16	10	35, 22		38.3	27.0	25.5
Jan-21	11	29, 21	22.0	32.8	24.2	25.4
Jan-22	12	33, 22	24.1	36.9	27.6	26.2
Jan-23	13	32, 22	25.1	39.0	24.5	24.1
Jan-29	14	33, 22	24.1	35.3	27.5	26.5
Jan-30	15	34, 23	24.1	34.9	29.7	28.0
Jan-31	16	37, 21	24.0	43.0	37.4	29.0
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			23.4	34.5	27.4	25.4

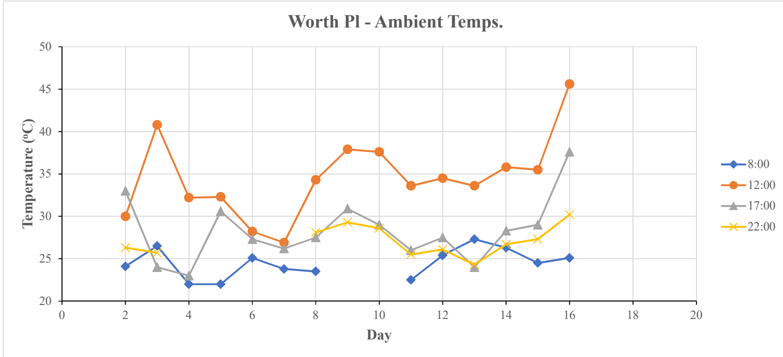
Surface (Location 9)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	20.4	53.7	20.7	24.5
Jan-09	3	30, 22	26.8	31.2	17.1	25.7
Jan-10	4	27, 21	23.8	44.2	19.1	
Jan-11	5	26, 19	24.7	40.8	28.8	
Jan-12	6	33, 20	20.4	58.3	28.7	
Jan-13	7	31, 21	22.6	47.8	24.1	
Jan-14	8	29, 20	25.2	46.2	14.3	24.0
Jan-15	9	34, 21		49.3	33.9	28.0
Jan-16	10	35, 22		51.9	20.0	26.9
Jan-21	11	29, 21	24.1	43.3	22.0	26.6
Jan-22	12	33, 22	26.5	48.7	20.0	26.7
Jan-23	13	32, 22	28.5	48.8	20.7	25.9
Jan-29	14	33, 22	26.3	45.3	22.9	26.6
Jan-30	15	34, 23	27.9	45.1	24.8	29.5
Jan-31	16	37, 21	28.3	53.6	33.4	30.6
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			25.0	47.2	23.4	26.8

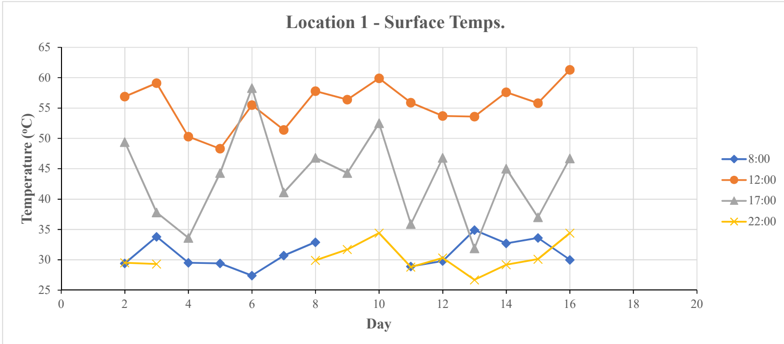
Site 1 – Watt Street																			
Date	Temperature Readings (°C)																		
Monday, 7 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		(Rainy day)
Time	Surface (Grass)	Air	Surface (Grass)	Air	Surface (Grass)	Air	Surface (Concrete)	Air	Surface (Asphalt)	Air	Surface (Asphalt)	Air	Surface (Asphalt)	Air	Surface (Asphalt)	Air	Surface (Asphalt)	Air	
07:30:00	19.3	20.6	20.4	20.6	20.3	20.6	19.9	20.6	19.9	20.6	20.1	20.6	18.8	20.6	18.5	20.6	17.9	20.6	
11:30:00	29.5	22.1	29.7	22.1	27.6	22.1	23.3	22.1	24.0	22.1	26.4	22.1	25.3	22.1	22.5	22.1	22.2	22.1	
16:30:00	23.4	25.2	23.2	25.2	23.0	25.2	22.0	25.2	23.6	25.2	23.8	25.2	23.1	25.2	21.8	25.2	21.2	25.2	
21:30:00	20.6	22.0	20.9	22.0	21.3	22.0	22.4	22.0	22.2	22.0	22.2	22.0	22.2	22.0	21.6	22.0	21.9	22.0	
Tuesday, 8 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		(Sunny, 28/21)
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
07:30:00	26.1	23.0	26.0	23.0	26.2	23.0	22.0	23.0	22.5	23.0	25.2	23.0	21.9	23.0	20.5	23.0	20.4	23.0	
11:30:00	34.4	29.7	35.7	29.7	41.2	29.7	23.5	29.7	52.4	29.7	55.9	29.7	50.3	29.7	51.5	29.7	53.7	29.7	
16:30:00	24.9	32.2	21.8	32.2	27.9	32.2	29.3	32.2	22.1	32.2	22.7	32.2	20.7	32.2	20.0	32.2	20.7	32.2	
21:30:00	19.4	22.0	20.1	22.0	20.4	22.0	24.0	22.0	22.3	22.0	23.4	22.0	23.8	22.0	23.2	22.0	24.5	22.0	
Wednesday, 9 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		(Sunny, 30/22)
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
07:30:00	29.7	24.0	31.4	24.0	30.3	24.0	26.9	24.0	27.2	24.0	28.9	24.0	27.4	24.0	26.5	24.0	26.8	24.0	
11:30:00	36.3	37.1	42.9	37.1	47.2	37.1	39.8	37.1	37.0	37.1	48.9	37.1	43.0	37.1	49.0	37.1	31.2	37.1	
16:30:00	22.3	23.0	22.8	23.0	19.5	23.0	20.4	23.0	22.6	23.0	24.3	23.0	21.5	23.0	16.0	23.0	17.1	23.0	
21:30:00	20.6	23.3	20.8	23.3	20.6	23.3	24.9	23.3	23.8	23.3	23.2	23.3	24.6	23.3	24.0	23.3	25.7	23.3	
Thursday, 10 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		(Cloudy, 27/21)
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
07:30:00	25.5	22.0	25.4	22.0	25.9	22.0	25.8	22.0	26.0	22.0	25.8	22.0	24.7	22.0	23.4	22.0	23.8	22.0	
11:30:00	33.9	31.3	35.1	31.3	35.8	31.3	27.6	31.3	44.0	31.3	46.8	31.3	49.1	31.3	45.0	31.3	44.2	31.3	
16:30:00	24.0	23.0	21.7	23.0	22.3	23.0	25.2	23.0	23.1	23.0	23.8	23.0	21.8	23.0	16.2	23.0	19.1	23.0	
21:30:00																			
Friday, 11 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		(Cloudy, 26/19)
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
07:30:00	25.8	22.0	26.0	22.0	27.3	22.0	26.2	22.0	26.0	22.0	26.4	22.0	25.6	22.0	23.6	22.0	24.7	22.0	
11:30:00	34.3	30.9	37.2	30.9	35.6	30.9	29.9	30.9	41.4	30.9	41.6	30.9	45.3	30.9	43.5	30.9	40.8	30.9	
16:30:00	24.9	27.0	26.9	27.0	23.3	27.0	19.8	27.0	28.0	27.0	31.2	27.0	27.4	27.0	26.1	27.0	28.8	27.0	
21:30:00																			
Saturday, 12 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		(Sunny, 33/20)
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
07:30:00	26.8	23.5	26.8	23.5	24.2	23.5	25.9	23.5	22.3	23.5	23.0	23.5	20.9	23.5	20.5	23.5	20.4	23.5	
11:30:00	35.2	26.9	37.7	26.9	44.3	26.9	23.7	26.9	55.4	26.9	58.0	26.9	54.6	26.9	55.9	26.9	58.3	26.9	
16:30:00	34.9	27.3	34.8	27.3	52.1	27.3	43.5	27.3	29.8	27.3	31.0	27.3	29.4	27.3	28.8	27.3	28.7	27.3	
21:30:00																			
Sunday, 13 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		(Sunny, 31/21)
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
07:30:00	22.2	23.0	22.5	23.0	24.0	23.0	23.8	23.0	23.0	23.0	22.9	23.0	22.5	23.0	22.4	23.0	22.6	23.0	
11:30:00	34.4	26.2	36.7	26.2	38.6	26.2	27.1	26.2	46.9	26.2	48.8	26.2	49.7	26.2	48.1	26.2	47.8	26.2	
16:30:00	31.3	25.7	37.0	25.7	45.8	25.7	40.2	25.7	28.6	25.7	30.1	25.7	28.1	25.7	25.6	25.7	24.1	25.7	
21:30:00																			
Monday, 14 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		(Sunny/cloud, 29/20) (Did rain)
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
07:30:00	26.4	23.5	27.4	23.5	27.0	23.5	26.5	23.5	26.6	23.5	28.0	23.5	26.4	23.5	25.5	23.5	25.2	23.5	
11:30:00	33.6	35.5	35.1	35.5	35.0	35.5	29.5	35.5	43.0	35.5	46.6	35.5	45.2	35.5	47.8	35.5	46.2	35.5	
16:30:00	14.8	27.0	14.4	27.0	16.1	27.0	27.7	27.0	10.2	27.0	14.5	27.0	14.2	27.0	13.8	27.0	14.3	27.0	
21:30:00	23.3	23.2	21.6	23.2	22.2	23.2	25.0	23.2	26.3	23.2	25.4	23.2	27.9	23.2	26.4	23.2	24.0	23.2	
Tuesday, 15 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		(Sunny, 34/21)
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
07:30:00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
11:30:00	37.2	40.4	36.9	40.4	35.5	40.4	31.4	40.4	46.5	40.4	49.2	40.4	53.2	40.4	51.7	40.4	49.3	40.4	
16:30:00	30.6	28.0	34.4	28.0	32.6	28.0	28.8	28.0	39.4	28.0	39.1	28.0	36.0	28.0	31.8	28.0	33.9	28.0	
21:30:00	19.8	26.7	20.6	26.7	18.4	26.7	22.2	26.7	26.5	26.7	24.4	26.7	25.9	26.7	25.3	26.7	28.0	26.7	
Wednesday, 16 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		(Sunny, 35/22)
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
07:30:00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
11:30:00	40.4	38.3	38.7	38.3	39.9	38.3	34.2	38.3	48.3	38.3	46.1	38.3	46.5	38.3	49.4	38.3	51.9	38.3	
16:30:00	21.8	27.0	24.4	27.0	28.4	27.0	29.7	27.0	21.4	27.0	23.3	27.0	19.4	27.0	20.2	27.0	20.0	27.0	
21:30:00	23.4	25.5	25.0	25.5	23.9	25.5	21.4	25.5	29.3	25.5	24.5	25.5	25.6	25.5	25.7	25.5	26.9	25.5	
Thursday, 17 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
07:30:00																			
11:30:00																			
16:30:00																			
21:30:00																			
Friday, 18 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		

Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
07:30:00																			
11:30:00																			
16:30:00																			
21:30:00																			
Saturday, 19 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		**Data Logger no. 9**		
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	
07:30:00																			
11:30:00																			
16:30:00																			
21:30:00																			
Sunday, 20 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		**Data Logger no. 9**		
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	
07:30:00																			
11:30:00																			
16:30:00																			
21:30:00																			
Monday, 21 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		**Data Logger no. 9**		
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	(Cloudy, 29/21)
07:30:00	26.0	22.0	25.7	22.0	25.3	22.0	25.5	22.0	25.6	22.0	25.9	22.0	25.0	22.0	23.9	22.0	24.1	22.0	
11:30:00	32.3	32.8	33.3	32.8	35.3	32.8	30.1	32.8	41.5	32.8	42.6	32.8	42.9	32.8	45.1	32.8	43.3	32.8	
16:30:00	25.2	24.2	27.8	24.2	25.0	24.2	27.5	24.2	22.6	24.2	25.7	24.2	25.0	24.2	23.5	24.2	22.0	24.2	
21:30:00	24.6	25.4	24.2	25.4	23.5	25.4	21.0	25.4	27.4	25.4	26.8	25.4	26.7	25.4	27.3	25.4	26.6	25.4	
Tuesday, 22 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		**Data Logger no. 9**		
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	(Sunny, 33/22)
07:30:00	27.3	24.1	28.1	24.1	27.7	24.1	26.5	24.1	26.4	24.1	28.0	24.1	27.2	24.1	26.3	24.1	26.5	24.1	
11:30:00	38.1	36.9	35.4	36.9	35.8	36.9	31.2	36.9	44.0	36.9	44.9	36.9	45.6	36.9	44.2	36.9	48.7	36.9	
16:30:00	22.1	27.6	28.5	27.6	26.4	27.6	30.9	27.6	19.5	27.6	22.2	27.6	21.5	27.6	17.2	27.6	20.0	27.6	
21:30:00	20.3	26.2	22.2	26.2	23.2	26.2	24.0	26.2	27.2	26.2	26.5	26.2	25.3	26.2	28.2	26.2	26.7	26.2	
Wednesday, 23 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		**Data Logger no. 9**		
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	(Sunny/Cloudy, 32/22)
07:30:00	27.9	25.1	28.2	25.1	29.7	25.1	28.2	25.1	28.3	25.1	33.1	25.1	34.2	25.1	28.4	25.1	28.5	25.1	
11:30:00	36.6	39.0	37.3	39.0	35.9	39.0	32.1	39.0	45.6	39.0	46.7	39.0	45.2	39.0	46.7	39.0	48.8	39.0	
16:30:00	21.0	24.5	22.7	24.5	22.6	24.5	22.3	24.5	24.0	24.5	24.2	24.5	22.6	24.5	21.1	24.5	20.7	24.5	
21:30:00	22.6	24.1	23.5	24.1	22.1	24.1	20.8	24.1	28.2	24.1	26.7	24.1	26.9	24.1	27.3	24.1	25.9	24.1	
Thursday, 24 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		**Data Logger no. 9**		
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	
07:30:00																			
11:30:00																			
16:30:00																			
21:30:00																			
Friday, 25 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		**Data Logger no. 9**		
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	
07:30:00																			
11:30:00																			
16:30:00																			
21:30:00																			
Saturday, 26 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		**Data Logger no. 9**		
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	
07:30:00																			
11:30:00																			
16:30:00																			
21:30:00																			
Sunday, 27 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		**Data Logger no. 9**		
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	
07:30:00																			
11:30:00																			
16:30:00																			
21:30:00																			
Monday, 28 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		**Data Logger no. 9**		
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	
07:30:00																			
11:30:00																			
16:30:00																			
21:30:00																			
Tuesday, 29 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		**Data Logger no. 9**		
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	(Sunny, 33/22)
07:30:00	29.7	24.1	28.1	24.1	31.6	24.1	28.1	24.1	27.8	24.1	28.1	24.1	27.4	24.1	24.2	24.1	26.3	24.1	
11:30:00	37.6	35.3	37.2	35.3	38.1	35.3	34.4	35.3	44.8	35.3	42.9	35.3	46.6	35.3	46.0	35.3	45.3	35.3	
16:30:00	23.7	27.5	23.9	27.5	33.7	27.5	33.2	27.5	19.7	27.5	19.5	27.5	21.0	27.5	19.4	27.5	22.9	27.5	
21:30:00	23.0	26.5	22.4	26.5	20.9	26.5	21.0	26.5	26.7	26.5	27.3	26.5	29.0	26.5	27.4	26.5	26.6	26.5	

Wednesday, 30 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
07:30:00	27.3	24.1	28.1	24.1	28.3	24.1	27.5	24.1	27.2	24.1	27.7	24.1	27.1	24.1	26.5	24.1	27.9	24.1	(Sunny/Cloudy, 34/23)
11:30:00	35.3	34.9	36.1	34.9	36.7	34.9	31.5	34.9	44.3	34.9	45.9	34.9	44.6	34.9	43.8	34.9	45.1	34.9	
16:30:00	20.9	29.7	19.7	29.7	30.3	29.7	25.8	29.7	20.4	29.7	22.4	29.7	21.5	29.7	21.3	29.7	24.8	29.7	
21:30:00	23.5	28.0	24.1	28.0	22.0	28.0	22.3	28.0	25.9	28.0	27.8	28.0	28.4	28.0	28.0	28.0	29.5	28.0	
Thursday, 31 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
07:30:00	26.9	24.0	26.9	24.0	28.9	24.0	27.6	24.0	27.6	24.0	28.6	24.0	27.7	24.0	26.6	24.0	28.3	24.0	(Sunny, 37/21)
11:30:00	39.1	43.0	40.6	43.0	38.4	43.0	35.8	43.0	49.5	43.0	51.3	43.0	52.0	43.0	50.8	43.0	53.6	43.0	
16:30:00	30.2	37.4	39.8	37.4	36.5	37.4	36.3	37.4	32.5	37.4	34.3	37.4	33.2	37.4	33.0	37.4	33.4	37.4	
21:30:00	24.4	29.0	23.5	29.0	23.8	29.0	24.2	29.0	27.6	29.0	28.9	29.0	26.5	29.0	29.3	29.0	30.6	29.0	

LOCATION 1 (Bluestone)





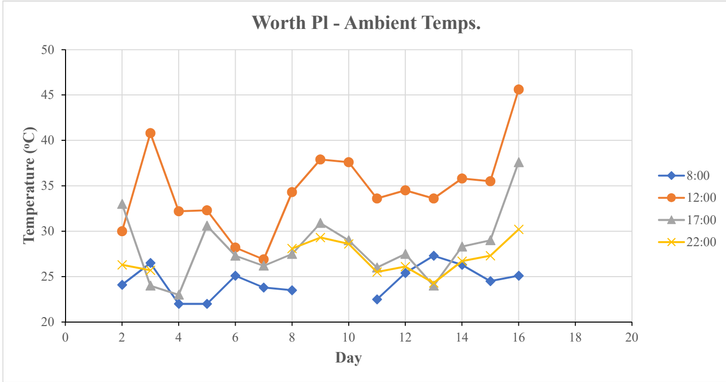
Ambient	
Time	Average Temp. (°C)
8:00:00	24.5
12:00:00	34.6
17:00:00	28.3
22:00:00	27.1

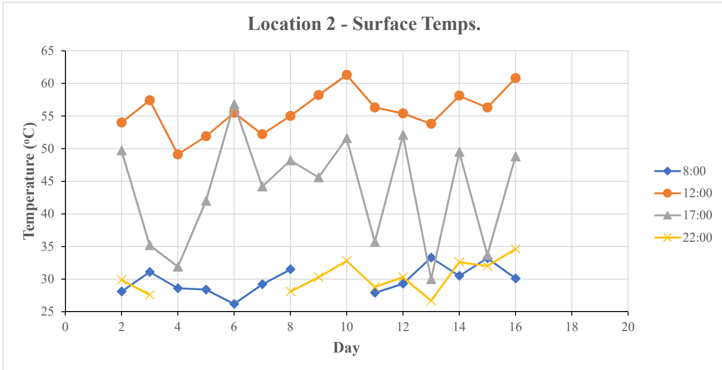
Surface	
Time	Average Temp. (°C)
8:00:00	31.0
12:00:00	55.6
17:00:00	43.4
22:00:00	30.4

Ambient (All of Worth Pl Sites)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	24.1	30.0	33.0	26.3
Jan-09	3	30, 22	26.5	40.8	24.0	25.7
Jan-10	4	27, 21	22.0	32.2	23.0	
Jan-11	5	26, 19	22.0	32.3	30.6	
Jan-12	6	33, 20	25.1	28.2	27.3	
Jan-13	7	31, 21	23.8	26.9	26.2	
Jan-14	8	29, 20	23.5	34.3	27.5	28.1
Jan-15	9	34, 21		37.9	30.9	29.3
Jan-16	10	35, 22		37.6	29.0	28.6
Jan-21	11	29, 21	22.5	33.6	26.0	25.5
Jan-22	12	33, 22	25.4	34.5	27.5	26.1
Jan-23	13	32, 22	27.3	33.6	24.0	24.3
Jan-29	14	33, 22	26.3	35.8	28.3	26.7
Jan-30	15	34, 23	24.5	35.5	29.0	27.3
Jan-31	16	37, 21	25.1	45.6	37.6	30.2
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			24.5	34.6	28.3	27.1

Surface (Location 1)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	29.4	56.9	49.4	29.5
Jan-09	3	30, 22	33.8	59.1	37.8	29.3
Jan-10	4	27, 21	29.5	50.3	33.6	
Jan-11	5	26, 19	29.4	48.3	44.3	
Jan-12	6	33, 20	27.4	55.5	58.3	
Jan-13	7	31, 21	30.7	51.4	41.1	
Jan-14	8	29, 20	32.9	57.8	46.8	29.9
Jan-15	9	34, 21		56.4	44.3	31.7
Jan-16	10	35, 22		59.9	52.5	34.4
Jan-21	11	29, 21	28.9	55.9	35.9	28.8
Jan-22	12	33, 22	29.8	53.7	46.8	30.3
Jan-23	13	32, 22	34.9	53.6	31.9	26.7
Jan-29	14	33, 22	32.7	57.6	45.0	29.2
Jan-30	15	34, 23	33.6	55.8	37.0	30.1
Jan-31	16	37, 21	30.0	61.3	46.7	34.4
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			31.0	55.6	43.4	30.4

LOCATION 2 (Bluestone)





Ambient	
Time	Average Temp. (°C)
8:00:00	24.5
12:00:00	34.6
17:00:00	28.3
22:00:00	27.1

Surface	
Time	Average Temp. (°C)
8:00:00	29.8
12:00:00	55.7
17:00:00	43.7
22:00:00	30.3

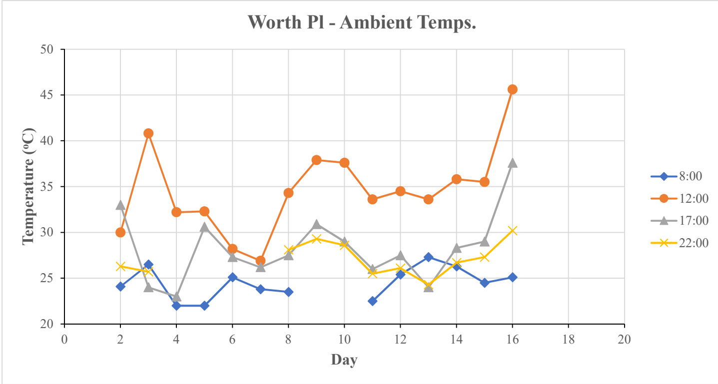
Ambient (All of Worth Pl Sites)

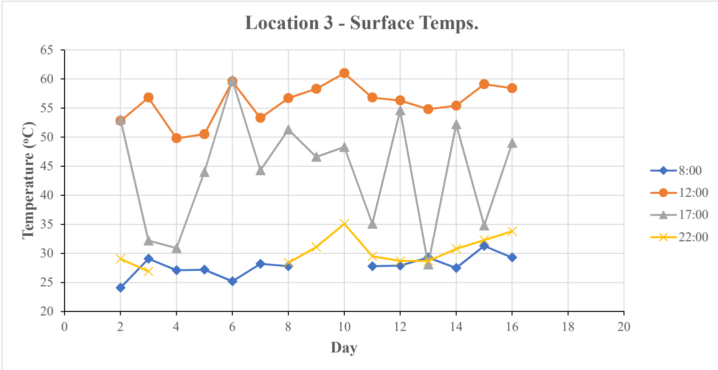
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	24.1	30.0	33.0	26.3
Jan-09	3	30, 22	26.5	40.8	24.0	25.7
Jan-10	4	27, 21	22.0	32.2	23.0	
Jan-11	5	26, 19	22.0	32.3	30.6	
Jan-12	6	33, 20	25.1	28.2	27.3	
Jan-13	7	31, 21	23.8	26.9	26.2	
Jan-14	8	29, 20	23.5	34.3	27.5	28.1
Jan-15	9	34, 21		37.9	30.9	29.3
Jan-16	10	35, 22		37.6	29.0	28.6
Jan-21	11	29, 21	22.5	33.6	26.0	25.5
Jan-22	12	33, 22	25.4	34.5	27.5	26.1
Jan-23	13	32, 22	27.3	33.6	24.0	24.3
Jan-29	14	33, 22	26.3	35.8	28.3	26.7
Jan-30	15	34, 23	24.5	35.5	29.0	27.3
Jan-31	16	37, 21	25.1	45.6	37.6	30.2
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			24.5	34.6	28.3	27.1

Surface (Location 2)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	28.1	54.0	49.7	29.9
Jan-09	3	30, 22	31.1	57.4	35.2	27.6
Jan-10	4	27, 21	28.6	49.1	31.9	
Jan-11	5	26, 19	28.4	51.9	42.0	
Jan-12	6	33, 20	26.2	55.5	56.8	
Jan-13	7	31, 21	29.2	52.2	44.2	
Jan-14	8	29, 20	31.5	55.0	48.2	28.1
Jan-15	9	34, 21		58.2	45.6	30.3
Jan-16	10	35, 22		61.3	51.6	32.8
Jan-21	11	29, 21	27.9	56.3	35.7	28.8
Jan-22	12	33, 22	29.3	55.4	52.1	30.3
Jan-23	13	32, 22	33.3	53.8	30.0	26.7
Jan-29	14	33, 22	30.5	58.1	49.5	32.6
Jan-30	15	34, 23	33.2	56.3	33.7	32.0
Jan-31	16	37, 21	30.1	60.8	48.8	34.6
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			29.8	55.7	43.7	30.3

LOCATION 3 (Bluestone)





Ambient	
Time	Average Temp. (°C)
8:00:00	24.5
12:00:00	34.6
17:00:00	28.3
22:00:00	27.1

Surface	
Time	Average Temp. (°C)
8:00:00	27.8
12:00:00	56.0
17:00:00	44.3
22:00:00	30.4

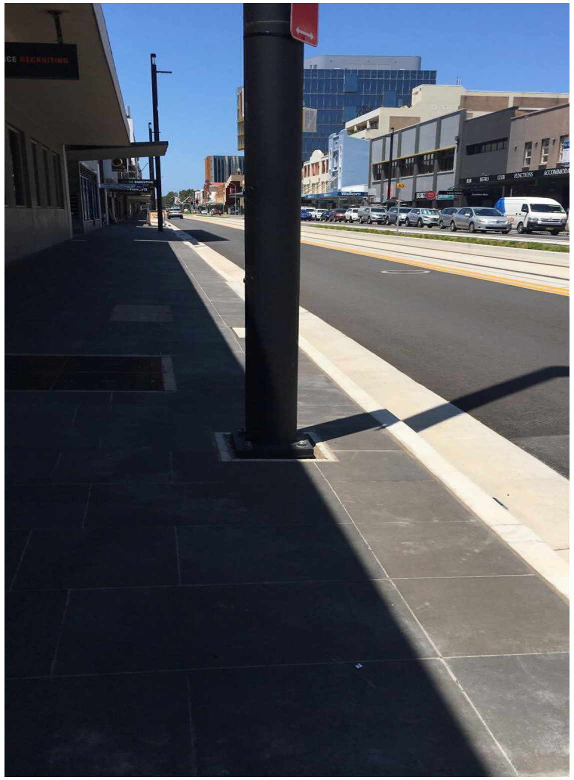
Ambient (All of Worth Pl Sites)

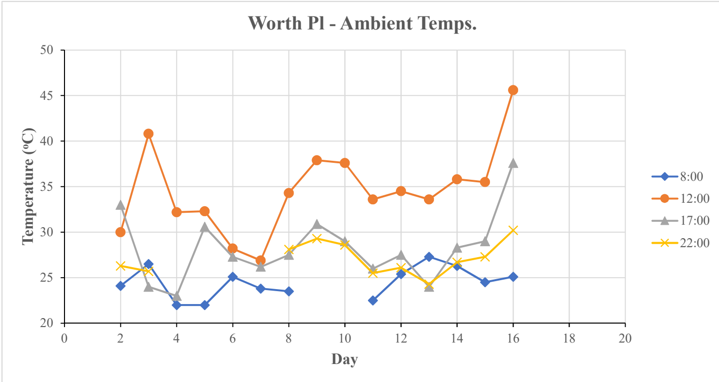
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	24.1	30.0	33.0	26.3
Jan-09	3	30, 22	26.5	40.8	24.0	25.7
Jan-10	4	27, 21	22.0	32.2	23.0	
Jan-11	5	26, 19	22.0	32.3	30.6	
Jan-12	6	33, 20	25.1	28.2	27.3	
Jan-13	7	31, 21	23.8	26.9	26.2	
Jan-14	8	29, 20	23.5	34.3	27.5	28.1
Jan-15	9	34, 21		37.9	30.9	29.3
Jan-16	10	35, 22		37.6	29.0	28.6
Jan-21	11	29, 21	22.5	33.6	26.0	25.5
Jan-22	12	33, 22	25.4	34.5	27.5	26.1
Jan-23	13	32, 22	27.3	33.6	24.0	24.3
Jan-29	14	33, 22	26.3	35.8	28.3	26.7
Jan-30	15	34, 23	24.5	35.5	29.0	27.3
Jan-31	16	37, 21	25.1	45.6	37.6	30.2
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			24.5	34.6	28.3	27.1

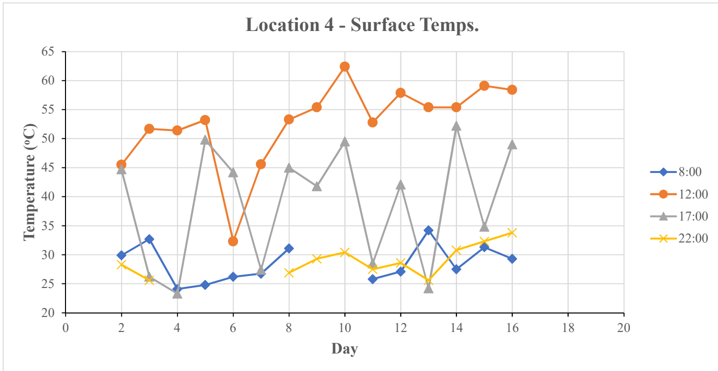
Surface (Location 3)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	24.1	52.8	53.0	29.1
Jan-09	3	30, 22	29.1	56.8	32.2	26.9
Jan-10	4	27, 21	27.1	49.8	30.9	
Jan-11	5	26, 19	27.2	50.5	44.0	
Jan-12	6	33, 20	25.2	59.6	59.8	
Jan-13	7	31, 21	28.2	53.3	44.3	
Jan-14	8	29, 20	27.8	56.7	51.3	28.4
Jan-15	9	34, 21		58.3	46.6	31.1
Jan-16	10	35, 22		61.0	48.3	35.1
Jan-21	11	29, 21	27.8	56.8	35.1	29.5
Jan-22	12	33, 22	27.9	56.3	54.6	28.7
Jan-23	13	32, 22	29.3	54.8	28.1	28.7
Jan-29	14	33, 22	27.5	55.4	52.2	30.8
Jan-30	15	34, 23	31.3	59.1	34.8	32.3
Jan-31	16	37, 21	29.3	58.4	49.0	33.8
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			27.8	56.0	44.3	30.4

LOCATION 4 (Bluestone)







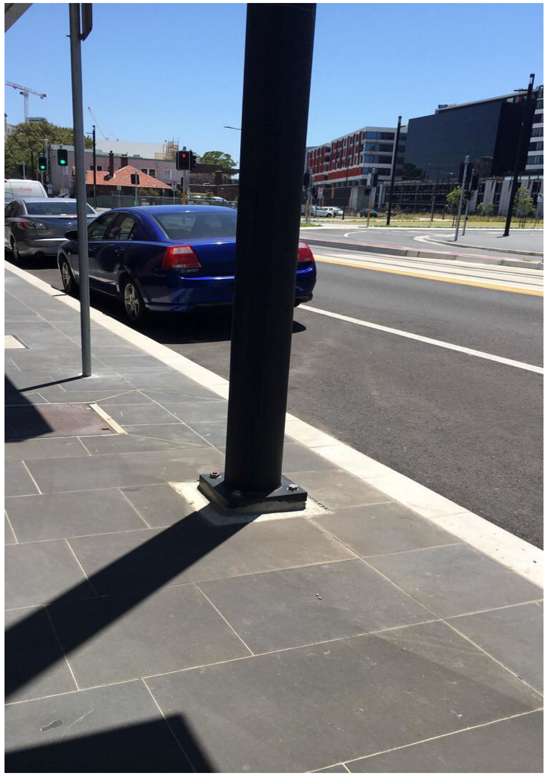
Ambient	
Time	Average Temp. (°C)
8:00:00	24.5
12:00:00	34.6
17:00:00	28.3
22:00:00	27.1

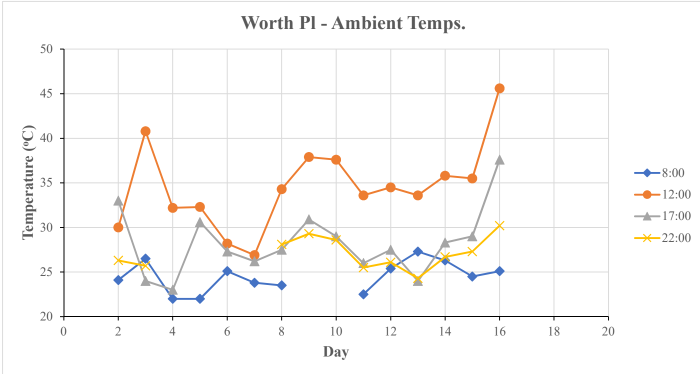
Surface	
Time	Average Temp. (°C)
8:00:00	28.5
12:00:00	52.7
17:00:00	38.8
22:00:00	29.0

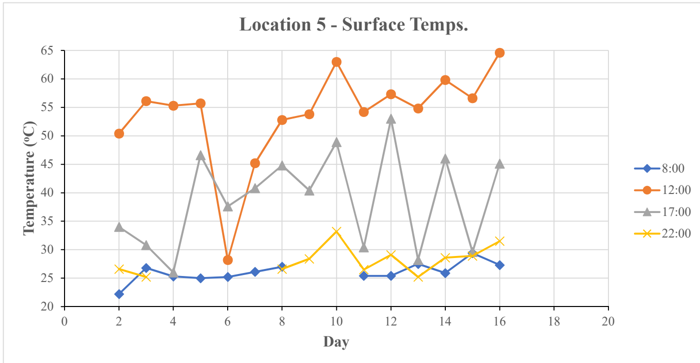
Ambient (All of Worth Pl Sites)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	24.1	30.0	33.0	26.3
Jan-09	3	30, 22	26.5	40.8	24.0	25.7
Jan-10	4	27, 21	22.0	32.2	23.0	
Jan-11	5	26, 19	22.0	32.3	30.6	
Jan-12	6	33, 20	25.1	28.2	27.3	
Jan-13	7	31, 21	23.8	26.9	26.2	
Jan-14	8	29, 20	23.5	34.3	27.5	28.1
Jan-15	9	34, 21		37.9	30.9	29.3
Jan-16	10	35, 22		37.6	29.0	28.6
Jan-21	11	29, 21	22.5	33.6	26.0	25.5
Jan-22	12	33, 22	25.4	34.5	27.5	26.1
Jan-23	13	32, 22	27.3	33.6	24.0	24.3
Jan-29	14	33, 22	26.3	35.8	28.3	26.7
Jan-30	15	34, 23	24.5	35.5	29.0	27.3
Jan-31	16	37, 21	25.1	45.6	37.6	30.2
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			24.5	34.6	28.3	27.1

Surface (Location 4)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	29.9	45.5	44.7	28.3
Jan-09	3	30, 22	32.7	51.7	26.2	25.6
Jan-10	4	27, 21	24.1	51.4	23.3	
Jan-11	5	26, 19	24.8	53.2	49.8	
Jan-12	6	33, 20	26.2	32.3	44.2	
Jan-13	7	31, 21	26.7	45.6	27.4	
Jan-14	8	29, 20	31.1	53.3	45.0	26.9
Jan-15	9	34, 21		55.4	41.8	29.3
Jan-16	10	35, 22		62.4	49.5	30.4
Jan-21	11	29, 21	25.8	52.8	28.5	27.5
Jan-22	12	33, 22	27.1	57.9	42.1	28.6
Jan-23	13	32, 22	34.2	55.4	24.2	25.6
Jan-29	14	33, 22	27.5	55.4	52.2	30.8
Jan-30	15	34, 23	31.3	59.1	34.8	32.3
Jan-31	16	37, 21	29.3	58.4	49.0	33.8
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			28.5	52.7	38.8	29.0

LOCATION 5 (Bluestone)







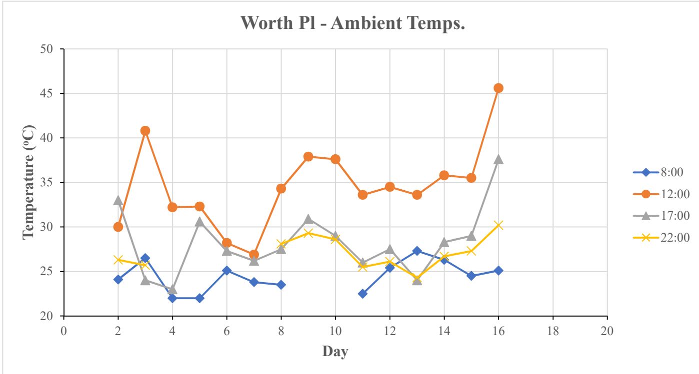
Ambient	
Time	Average Temp. (°C)
8:00:00	24.5
12:00:00	34.6
17:00:00	28.3
22:00:00	27.1

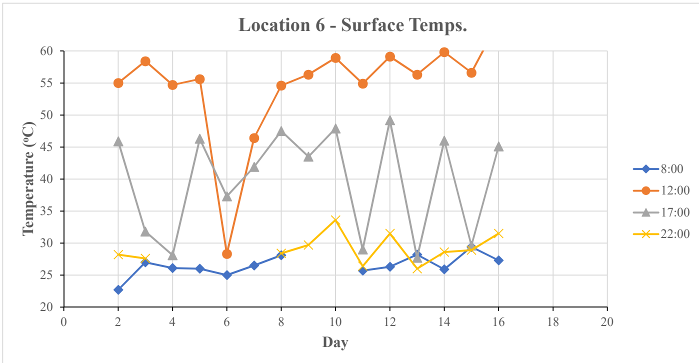
Surface	
Time	Average Temp. (°C)
8:00:00	26.0
12:00:00	53.9
17:00:00	38.8
22:00:00	28.2

Ambient (All of Worth Pl Sites)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	24.1	30.0	33.0	26.3
Jan-09	3	30, 22	26.5	40.8	24.0	25.7
Jan-10	4	27, 21	22.0	32.2	23.0	
Jan-11	5	26, 19	22.0	32.3	30.6	
Jan-12	6	33, 20	25.1	28.2	27.3	
Jan-13	7	31, 21	23.8	26.9	26.2	
Jan-14	8	29, 20	23.5	34.3	27.5	28.1
Jan-15	9	34, 21		37.9	30.9	29.3
Jan-16	10	35, 22		37.6	29.0	28.6
Jan-21	11	29, 21	22.5	33.6	26.0	25.5
Jan-22	12	33, 22	25.4	34.5	27.5	26.1
Jan-23	13	32, 22	27.3	33.6	24.0	24.3
Jan-29	14	33, 22	26.3	35.8	28.3	26.7
Jan-30	15	34, 23	24.5	35.5	29.0	27.3
Jan-31	16	37, 21	25.1	45.6	37.6	30.2
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			24.5	34.6	28.3	27.1

Surface (Location 5)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	22.2	50.4	34.0	26.6
Jan-09	3	30, 22	26.8	56.1	30.8	25.2
Jan-10	4	27, 21	25.3	55.3	26.0	
Jan-11	5	26, 19	25.0	55.7	46.6	
Jan-12	6	33, 20	25.2	28.2	37.6	
Jan-13	7	31, 21	26.1	45.2	40.8	
Jan-14	8	29, 20	27.0	52.8	44.8	26.6
Jan-15	9	34, 21		53.8	40.4	28.4
Jan-16	10	35, 22		63.0	48.9	33.2
Jan-21	11	29, 21	25.4	54.2	30.4	26.5
Jan-22	12	33, 22	25.4	57.3	53.0	29.1
Jan-23	13	32, 22	27.5	54.8	28.2	25.2
Jan-29	14	33, 22	25.9	59.8	46.0	28.6
Jan-30	15	34, 23	29.4	56.6	29.6	28.9
Jan-31	16	37, 21	27.3	64.6	45.1	31.5
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			26.0	53.9	38.8	28.2

LOCATION 6 (Bluestone)





Ambient	
Time	Average Temp. (°C)
8:00:00	24.5
12:00:00	34.6
17:00:00	28.3
22:00:00	27.1

Surface	
Time	Average Temp. (°C)
8:00:00	26.5
12:00:00	54.6
17:00:00	39.8
22:00:00	29.1

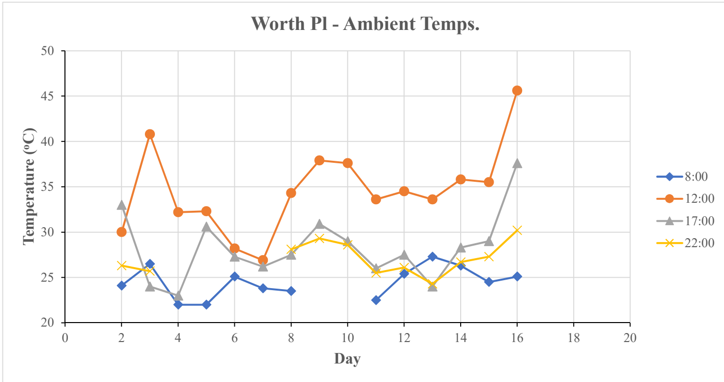
Ambient (All of Worth Pl Sites)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	24.1	30.0	33.0	26.3
Jan-09	3	30, 22	26.5	40.8	24.0	25.7
Jan-10	4	27, 21	22.0	32.2	23.0	
Jan-11	5	26, 19	22.0	32.3	30.6	
Jan-12	6	33, 20	25.1	28.2	27.3	
Jan-13	7	31, 21	23.8	26.9	26.2	
Jan-14	8	29, 20	23.5	34.3	27.5	28.1
Jan-15	9	34, 21		37.9	30.9	29.3
Jan-16	10	35, 22		37.6	29.0	28.6
Jan-21	11	29, 21	22.5	33.6	26.0	25.5
Jan-22	12	33, 22	25.4	34.5	27.5	26.1
Jan-23	13	32, 22	27.3	33.6	24.0	24.3
Jan-29	14	33, 22	26.3	35.8	28.3	26.7
Jan-30	15	34, 23	24.5	35.5	29.0	27.3
Jan-31	16	37, 21	25.1	45.6	37.6	30.2
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			24.5	34.6	28.3	27.1

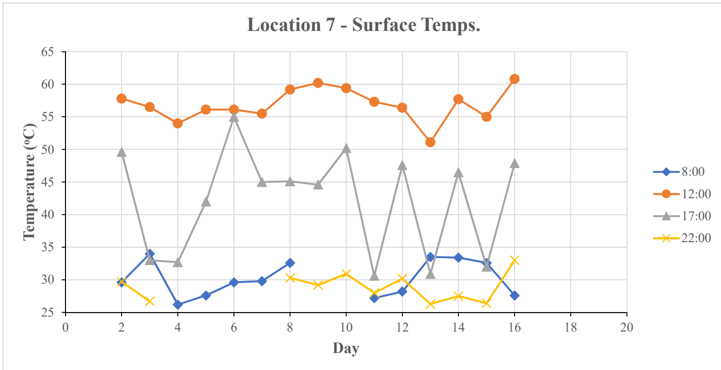
Surface (Location 6)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	22.7	55.0	45.9	28.2
Jan-09	3	30, 22	27.0	58.4	31.8	27.6
Jan-10	4	27, 21	26.1	54.7	28.1	
Jan-11	5	26, 19	26.0	55.6	46.3	
Jan-12	6	33, 20	25.0	28.3	37.3	
Jan-13	7	31, 21	26.5	46.4	41.9	
Jan-14	8	29, 20	28.1	54.6	47.5	28.4
Jan-15	9	34, 21		56.3	43.5	29.7
Jan-16	10	35, 22		58.9	47.9	33.6
Jan-21	11	29, 21	25.7	54.9	29.0	26.4
Jan-22	12	33, 22	26.3	59.1	49.2	31.5
Jan-23	13	32, 22	28.2	56.3	27.7	26.0
Jan-29	14	33, 22	25.9	59.8	46.0	28.6
Jan-30	15	34, 23	29.4	56.6	29.6	28.9
Jan-31	16	37, 21	27.3	64.6	45.1	31.5
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			26.5	54.6	39.8	29.1

LOCATION 7 (Bluestone)



Ambient	
Time	Average Temp. (°C)
8:00:00	24.5
12:00:00	34.6
17:00:00	28.3
22:00:00	27.1



Surface	
Time	Average Temp. (°C)
8:00:00	30.1
12:00:00	56.9
17:00:00	42.2
22:00:00	28.9

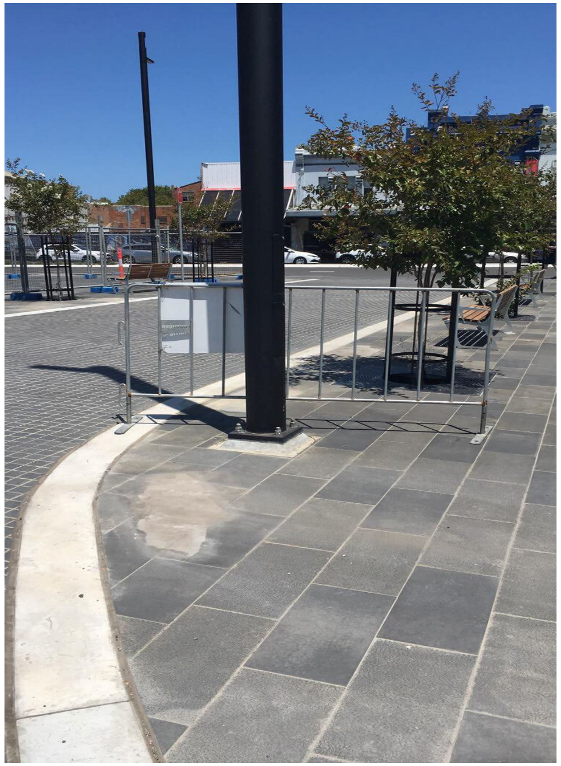
Ambient (All of Worth Pl Sites)

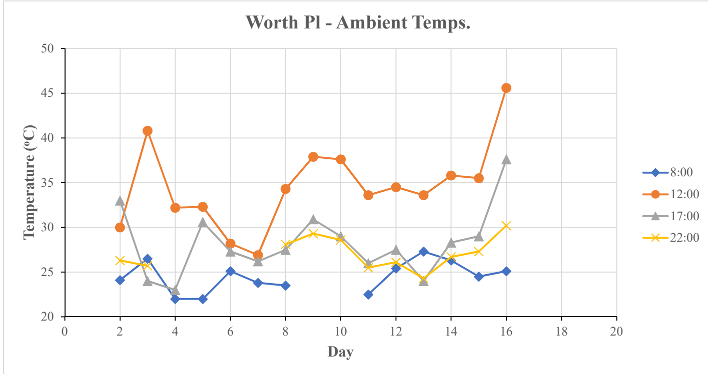
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	24.1	30.0	33.0	26.3
Jan-09	3	30, 22	26.5	40.8	24.0	25.7
Jan-10	4	27, 21	22.0	32.2	23.0	
Jan-11	5	26, 19	22.0	32.3	30.6	
Jan-12	6	33, 20	25.1	28.2	27.3	
Jan-13	7	31, 21	23.8	26.9	26.2	
Jan-14	8	29, 20	23.5	34.3	27.5	28.1
Jan-15	9	34, 21		37.9	30.9	29.3
Jan-16	10	35, 22		37.6	29.0	28.6
Jan-21	11	29, 21	22.5	33.6	26.0	25.5
Jan-22	12	33, 22	25.4	34.5	27.5	26.1
Jan-23	13	32, 22	27.3	33.6	24.0	24.3
Jan-29	14	33, 22	26.3	35.8	28.3	26.7
Jan-30	15	34, 23	24.5	35.5	29.0	27.3
Jan-31	16	37, 21	25.1	45.6	37.6	30.2
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			24.5	34.6	28.3	27.1

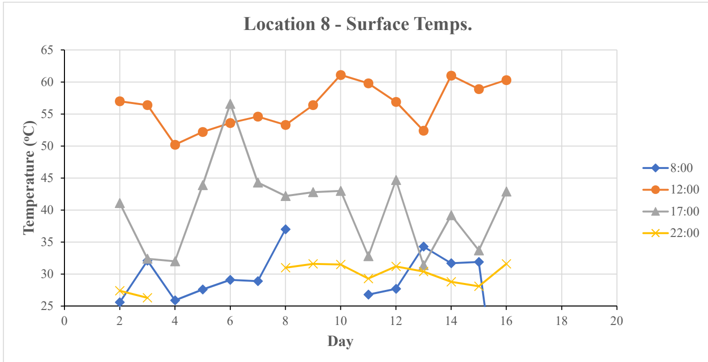
Surface (Location 7)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	29.6	57.8	49.6	29.7
Jan-09	3	30, 22	34.0	56.5	33.0	26.7
Jan-10	4	27, 21	26.2	54.0	32.7	
Jan-11	5	26, 19	27.6	56.1	42.0	
Jan-12	6	33, 20	29.6	56.1	55.0	
Jan-13	7	31, 21	29.8	55.5	45.0	
Jan-14	8	29, 20	32.6	59.2	45.1	30.3
Jan-15	9	34, 21		60.2	44.6	29.2
Jan-16	10	35, 22		59.4	50.2	30.9
Jan-21	11	29, 21	27.2	57.3	30.6	28.0
Jan-22	12	33, 22	28.2	56.4	47.6	30.2
Jan-23	13	32, 22	33.5	51.1	30.9	26.3
Jan-29	14	33, 22	33.4	57.7	46.5	27.5
Jan-30	15	34, 23	32.6	55.0	32.0	26.4
Jan-31	16	37, 21	27.6	60.8	47.9	33.0
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			30.1	56.9	42.2	28.9

LOCATION 8 (Bluestone)







Ambient	
Time	Average Temp. (°C)
8:00:00	24.5
12:00:00	34.6
17:00:00	28.3
22:00:00	27.1

Surface	
Time	Average Temp. (°C)
8:00:00	29.9
12:00:00	56.3
17:00:00	40.2
22:00:00	29.7

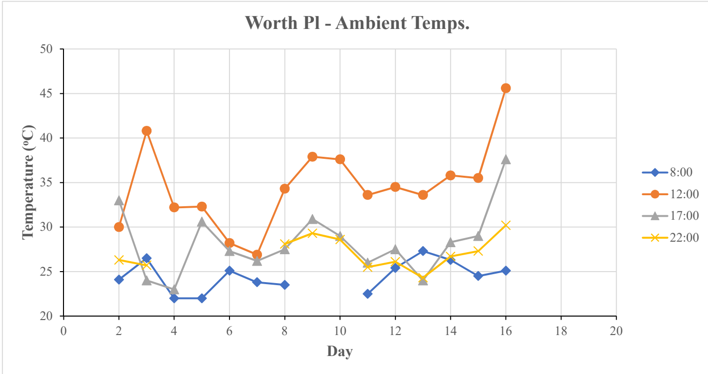
Ambient (All of Worth Pl Sites)

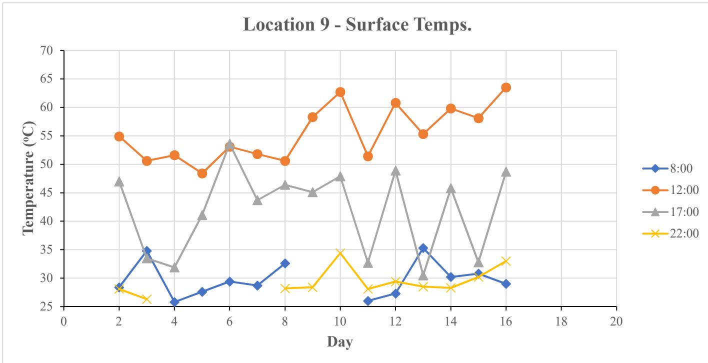
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	24.1	30.0	33.0	26.3
Jan-09	3	30, 22	26.5	40.8	24.0	25.7
Jan-10	4	27, 21	22.0	32.2	23.0	
Jan-11	5	26, 19	22.0	32.3	30.6	
Jan-12	6	33, 20	25.1	28.2	27.3	
Jan-13	7	31, 21	23.8	26.9	26.2	
Jan-14	8	29, 20	23.5	34.3	27.5	28.1
Jan-15	9	34, 21		37.9	30.9	29.3
Jan-16	10	35, 22		37.6	29.0	28.6
Jan-21	11	29, 21	22.5	33.6	26.0	25.5
Jan-22	12	33, 22	25.4	34.5	27.5	26.1
Jan-23	13	32, 22	27.3	33.6	24.0	24.3
Jan-29	14	33, 22	26.3	35.8	28.3	26.7
Jan-30	15	34, 23	24.5	35.5	29.0	27.3
Jan-31	16	37, 21	25.1	45.6	37.6	30.2
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			24.5	34.6	28.3	27.1

Surface (Location 8)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	25.6	57.0	41.1	27.4
Jan-09	3	30, 22	32.1	56.4	32.4	26.3
Jan-10	4	27, 21	25.9	50.2	32.0	
Jan-11	5	26, 19	27.6	52.2	43.9	
Jan-12	6	33, 20	29.1	53.6	56.6	
Jan-13	7	31, 21	28.9	54.6	44.3	
Jan-14	8	29, 20	37.0	53.3	42.2	31.0
Jan-15	9	34, 21		56.4	42.8	31.6
Jan-16	10	35, 22		61.1	43.0	31.5
Jan-21	11	29, 21	26.8	59.8	32.8	29.3
Jan-22	12	33, 22	27.7	56.9	44.7	31.2
Jan-23	13	32, 22	34.3	52.4	31.4	30.4
Jan-29	14	33, 22	31.7	61.0	39.2	28.8
Jan-30	15	34, 23	31.9	58.9	33.7	28.1
Jan-31	16	37, 21	-	60.3	42.9	31.6
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			29.9	56.3	40.2	29.7

LOCATION 9 (Bluestone)





Ambient	
Time	Average Temp. (°C)
8:00:00	24.5
12:00:00	34.6
17:00:00	28.3
22:00:00	27.1

Surface	
Time	Average Temp. (°C)
8:00:00	29.7
12:00:00	55.4
17:00:00	42.0
22:00:00	29.4

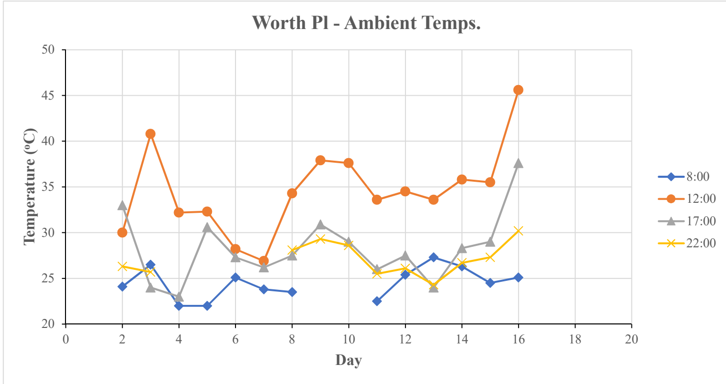
Ambient (All of Worth Pl Sites)

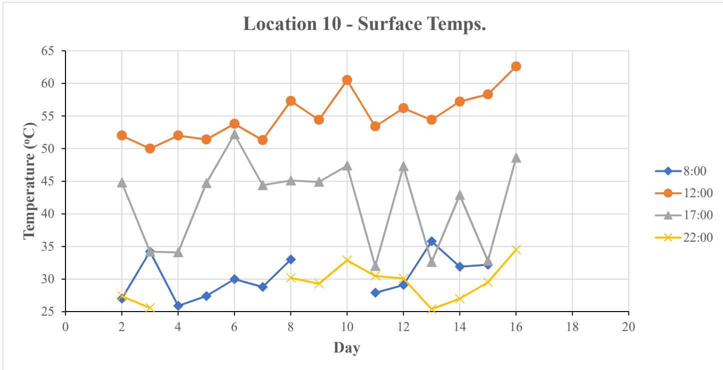
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	24.1	30.0	33.0	26.3
Jan-09	3	30, 22	26.5	40.8	24.0	25.7
Jan-10	4	27, 21	22.0	32.2	23.0	
Jan-11	5	26, 19	22.0	32.3	30.6	
Jan-12	6	33, 20	25.1	28.2	27.3	
Jan-13	7	31, 21	23.8	26.9	26.2	
Jan-14	8	29, 20	23.5	34.3	27.5	28.1
Jan-15	9	34, 21		37.9	30.9	29.3
Jan-16	10	35, 22		37.6	29.0	28.6
Jan-21	11	29, 21	22.5	33.6	26.0	25.5
Jan-22	12	33, 22	25.4	34.5	27.5	26.1
Jan-23	13	32, 22	27.3	33.6	24.0	24.3
Jan-29	14	33, 22	26.3	35.8	28.3	26.7
Jan-30	15	34, 23	24.5	35.5	29.0	27.3
Jan-31	16	37, 21	25.1	45.6	37.6	30.2
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			24.5	34.6	28.3	27.1

Surface (Location 9)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	28.4	54.9	47.0	28.1
Jan-09	3	30, 22	34.8	50.6	33.5	26.3
Jan-10	4	27, 21	25.8	51.6	31.9	
Jan-11	5	26, 19	27.6	48.4	41.1	
Jan-12	6	33, 20	29.4	53.1	53.6	
Jan-13	7	31, 21	28.7	51.8	43.7	
Jan-14	8	29, 20	32.6	50.6	46.4	28.2
Jan-15	9	34, 21		58.3	45.1	28.4
Jan-16	10	35, 22		62.7	47.9	34.4
Jan-21	11	29, 21	26.0	51.4	32.7	28.1
Jan-22	12	33, 22	27.3	60.8	48.9	29.4
Jan-23	13	32, 22	35.3	55.3	30.5	28.5
Jan-29	14	33, 22	30.2	59.8	45.8	28.3
Jan-30	15	34, 23	30.8	58.1	32.8	30.2
Jan-31	16	37, 21	29.0	63.5	48.7	33.0
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			29.7	55.4	42.0	29.4

LOCATION 10 (Bluestone)





Ambient	
Time	Average Temp. (°C)
8:00:00	24.5
12:00:00	34.6
17:00:00	28.3
22:00:00	27.1

Surface	
Time	Average Temp. (°C)
8:00:00	30.3
12:00:00	55.0
17:00:00	41.9
22:00:00	29.3

Ambient (All of Watt St Sites)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	24.1	30.0	33.0	26.3
Jan-09	3	30, 22	26.5	40.8	24.0	25.7
Jan-10	4	27, 21	22.0	32.2	23.0	
Jan-11	5	26, 19	22.0	32.3	30.6	
Jan-12	6	33, 20	25.1	28.2	27.3	
Jan-13	7	31, 21	23.8	26.9	26.2	
Jan-14	8	29, 20	23.5	34.3	27.5	28.1
Jan-15	9	34, 21		37.9	30.9	29.3
Jan-16	10	35, 22		37.6	29.0	28.6
Jan-21	11	29, 21	22.5	33.6	26.0	25.5
Jan-22	12	33, 22	25.4	34.5	27.5	26.1
Jan-23	13	32, 22	27.3	33.6	24.0	24.3
Jan-29	14	33, 22	26.3	35.8	28.3	26.7
Jan-30	15	34, 23	24.5	35.5	29.0	27.3
Jan-31	16	37, 21	25.1	45.6	37.6	30.2
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			24.5	34.6	28.3	27.1

Surface (Location 10)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	27.0	52.0	44.8	27.4
Jan-09	3	30, 22	34.2	50.0	34.2	25.6
Jan-10	4	27, 21	25.9	52.0	34.1	
Jan-11	5	26, 19	27.4	51.4	44.7	
Jan-12	6	33, 20	30.0	53.8	52.2	
Jan-13	7	31, 21	28.8	51.3	44.4	
Jan-14	8	29, 20	33.0	57.3	45.1	30.2
Jan-15	9	34, 21		54.4	44.9	29.3
Jan-16	10	35, 22		60.5	47.4	32.9
Jan-21	11	29, 21	27.9	53.4	32.0	30.5
Jan-22	12	33, 22	29.1	56.2	47.3	30.1
Jan-23	13	32, 22	35.8	54.4	32.6	25.4
Jan-29	14	33, 22	31.9	57.2	42.9	27.0
Jan-30	15	34, 23	32.2	58.3	32.8	29.5
Jan-31	16	37, 21		62.6	48.6	34.5
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			30.3	55.0	41.9	29.3

Site 2 – Worth Place

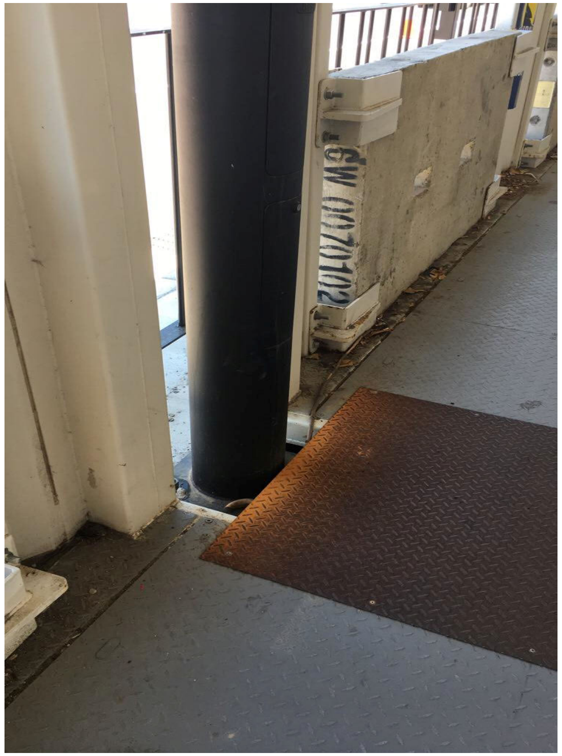
Date	Temperature Readings (°C)																				
Monday, 7 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface (Bluestone)	Air	Surface (Bluestone)	Air	Surface (Bluestone)	Air	Surface (Bluestone)	Air	Surface (Bluestone)	Air	Surface (Bluestone)	Air	Surface (Bluestone)	Air	Surface (Bluestone)	Air	Surface (Bluestone)	Air	Surface (Bluestone)	Air	
08:00:00	20.2	20.9	20.4	20.9	20.1	20.9	19.0	20.9	19.2	20.9	20.2	20.9	20.7	20.9	20.3	20.9	20.7	20.9	20.4	20.9	(Rainy day)
12:00:00	34.6	26.5	34.1	26.5	31.9	26.5	27.3	26.5	28.4	26.5	29.0	26.5	34.2	26.5	35.8	26.5	33.2	26.5	35.3	26.5	
17:00:00	32.1	26.5	32.1	26.5	31.6	26.5	24.6	26.5	26.1	26.5	28.0	26.5	31.3	26.5	31.9	26.5	31.3	26.5	30.5	26.5	
22:00:00	25.6	23.2	25.4	23.2	24.9	23.2	23.6	23.2	23.3	23.2	24.5	23.2	25.2	23.2	25.3	23.2	24.5	23.2	24.3	23.2	
Tuesday, 8 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00	29.4	24.1	28.1	24.1	24.1	24.1	29.9	24.1	22.2	24.1	22.7	24.1	29.6	24.1	25.6	24.1	28.4	24.1	27.0	24.1	(Sunny, 28/21)
12:00:00	56.9	30.0	54.0	30.0	52.8	30.0	45.5	30.0	50.4	30.0	55.0	30.0	57.8	30.0	57.0	30.0	54.9	30.0	52.0	30.0	
17:00:00	49.4	33.0	49.7	33.0	53.0	33.0	44.7	33.0	34.0	33.0	45.9	33.0	49.6	33.0	41.1	33.0	47.0	33.0	44.8	33.0	
22:00:00	29.5	26.3	29.9	26.3	29.1	26.3	28.3	26.3	26.6	26.3	28.2	26.3	29.7	26.3	27.4	26.3	28.1	26.3	27.4	26.3	
Wednesday, 9 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00	33.8	26.5	31.1	26.5	29.1	26.5	32.7	26.5	26.8	26.5	27.0	26.5	34.0	26.5	32.1	26.5	34.8	26.5	34.2	26.5	(Sunny, 30/22)
12:00:00	59.1	40.8	57.4	40.8	56.8	40.8	51.7	40.8	56.1	40.8	58.4	40.8	56.5	40.8	56.4	40.8	50.6	40.8	50.0	40.8	
17:00:00	37.8	24.0	35.2	24.0	32.2	24.0	26.2	24.0	30.8	24.0	31.8	24.0	33.0	24.0	32.4	24.0	33.5	24.0	34.2	24.0	
22:00:00	29.3	25.7	27.6	25.7	26.9	25.7	25.6	25.7	25.2	25.7	27.6	25.7	26.7	25.7	26.3	25.7	26.3	25.7	25.6	25.7	
Thursday, 10 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00	29.5	22.0	28.6	22.0	27.1	22.0	24.1	22.0	25.3	22.0	26.1	22.0	26.2	22.0	25.9	22.0	25.8	22.0	25.9	22.0	(Cloudy, 27/21)
12:00:00	50.3	32.2	49.1	32.2	49.8	32.2	51.4	32.2	55.3	32.2	54.7	32.2	54.0	32.2	50.2	32.2	51.6	32.2	52.0	32.2	
17:00:00	33.6	23.0	31.9	23.0	30.9	23.0	23.3	23.0	26.0	23.0	28.1	23.0	32.7	23.0	32.0	23.0	31.9	23.0	34.1	23.0	
22:00:00																					
Friday, 11 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00	29.4	22.0	28.4	22.0	27.2	22.0	24.8	22.0	25.0	22.0	26.0	22.0	27.6	22.0	27.6	22.0	27.6	22.0	27.4	22.0	(Cloudy, 26/19)
12:00:00	48.3	32.3	51.9	32.3	50.5	32.3	53.2	32.3	55.7	32.3	55.6	32.3	56.1	32.3	52.2	32.3	48.4	32.3	51.4	32.3	
17:00:00	44.3	30.6	42.0	30.6	44.0	30.6	49.8	30.6	46.6	30.6	46.3	30.6	42.0	30.6	43.9	30.6	41.1	30.6	44.7	30.6	
22:00:00																					
Saturday, 12 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00	27.4	25.1	26.2	25.1	25.2	25.1	26.2	25.1	25.2	25.1	25.0	25.1	29.6	25.1	29.1	25.1	29.4	25.1	30.0	25.1	(Sunny, 33/20)
12:00:00	55.5	28.2	55.5	28.2	59.6	28.2	32.3	28.2	28.2	28.2	28.3	28.2	56.1	28.2	53.6	28.2	53.1	28.2	53.8	28.2	
17:00:00	58.3	27.3	56.8	27.3	59.8	27.3	44.2	27.3	37.6	27.3	37.3	27.3	55.0	27.3	56.6	27.3	53.6	27.3	52.2	27.3	
22:00:00																					
Sunday, 13 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00	30.7	23.8	29.2	23.8	28.2	23.8	26.7	23.8	26.1	23.8	26.5	23.8	29.8	23.8	28.9	23.8	28.7	23.8	28.8	23.8	(Sunny, 31/21)
12:00:00	51.4	26.9	52.2	26.9	53.3	26.9	45.6	26.9	45.2	26.9	46.4	26.9	55.5	26.9	54.6	26.9	51.8	26.9	51.3	26.9	
17:00:00	41.1	26.2	44.2	26.2	44.3	26.2	27.4	26.2	40.8	26.2	41.9	26.2	45.0	26.2	44.3	26.2	43.7	26.2	44.4	26.2	
22:00:00																					
Monday, 14 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00	32.9	23.5	31.5	23.5	27.8	23.5	31.1	23.5	27.0	23.5	28.1	23.5	32.6	23.5	37.0	23.5	32.6	23.5	33.0	23.5	(Sunny/cloud, 29/20) (Did rain)
12:00:00	57.8	34.3	55.0	34.3	56.7	34.3	53.3	34.3	52.8	34.3	54.6	34.3	59.2	34.3	53.3	34.3	50.6	34.3	57.3	34.3	
17:00:00	46.8	27.5	48.2	27.5	51.3	27.5	45.0	27.5	44.8	27.5	47.5	27.5	45.1	27.5	42.2	27.5	46.4	27.5	45.1	27.5	
22:00:00	29.9	28.1	28.1	28.1	28.4	28.1	26.9	28.1	26.6	28.1	28.4	28.1	30.3	28.1	31.0	28.1	28.2	28.1	30.2	28.1	
Tuesday, 15 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(Sunny, 34/21)
12:00:00	56.4	37.9	58.2	37.9	58.3	37.9	55.4	37.9	53.8	37.9	56.3	37.9	60.2	37.9	56.4	37.9	58.3	37.9	54.4	37.9	
17:00:00	44.3	30.9	45.6	30.9	46.6	30.9	41.8	30.9	40.4	30.9	43.5	30.9	44.6	30.9	42.8	30.9	45.1	30.9	44.9	30.9	
22:00:00	31.7	29.3	30.3	29.3	31.1	29.3	29.3	29.3	28.4	29.3	29.7	29.3	29.2	29.3	31.6	29.3	28.4	29.3	29.3	29.3	
Wednesday, 16 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(Sunny, 35/22)
12:00:00	59.9	37.6	61.3	37.6	61.0	37.6	62.4	37.6	63.0	37.6	58.9	37.6	59.4	37.6	61.1	37.6	62.7	37.6	60.5	37.6	
17:00:00	52.5	29.0	51.6	29.0	48.3	29.0	49.5	29.0	48.9	29.0	47.9	29.0	50.2	29.0	43.0	29.0	47.9	29.0	47.4	29.0	
22:00:00	34.4	28.6	32.8	28.6	35.1	28.6	30.4	28.6	33.2	28.6	33.6	28.6	30.9	28.6	31.5	28.6	34.4	28.6	32.9	28.6	
Thursday, 17 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					
17:00:00																					
22:00:00																					
Friday, 18 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					
17:00:00																					
22:00:00																					
Saturday, 19 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					

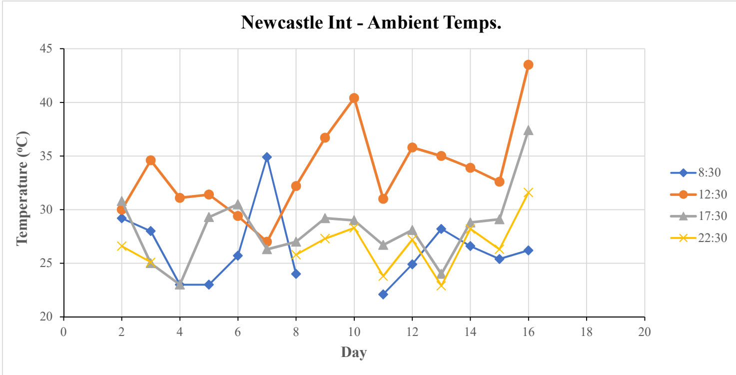
17:00:00																					
22:00:00																					
Sunday, 20 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					
17:00:00																					
22:00:00																					
Monday, 21 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00	28.9	22.5	27.9	22.5	27.8	22.5	25.8	22.5	25.4	22.5	25.7	22.5	27.2	22.5	26.8	22.5	26.0	22.5	27.9	22.5	(Cloudy, 29/21)
12:00:00	55.9	33.6	56.3	33.6	56.8	33.6	52.8	33.6	54.2	33.6	54.9	33.6	57.3	33.6	59.8	33.6	51.4	33.6	53.4	33.6	
17:00:00	35.9	26.0	35.7	26.0	35.1	26.0	28.5	26.0	30.4	26.0	29.0	26.0	30.6	26.0	32.8	26.0	32.7	26.0	32.0	26.0	
22:00:00	28.8	25.5	30.2	25.5	29.5	25.5	27.5	25.5	26.5	25.5	26.4	25.5	28.0	25.5	29.3	25.5	28.1	25.5	30.5	25.5	
Tuesday, 22 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00	29.8	25.4	29.3	25.4	27.9	25.4	27.1	25.4	25.4	25.4	26.3	25.4	28.2	25.4	27.7	25.4	27.3	25.4	29.1	25.4	(Sunny, 33/22)
12:00:00	53.7	34.5	55.4	34.5	56.3	34.5	57.9	34.5	57.3	34.5	59.1	34.5	56.4	34.5	56.9	34.5	60.8	34.5	56.2	34.5	
17:00:00	46.8	27.5	52.1	27.5	54.6	27.5	42.1	27.5	53.0	27.5	49.2	27.5	47.6	27.5	44.7	27.5	48.9	27.5	47.3	27.5	
22:00:00	30.3	26.1	31.4	26.1	28.7	26.1	28.6	26.1	29.1	26.1	31.5	26.1	30.2	26.1	31.2	26.1	29.4	26.1	30.1	26.1	
Wednesday, 23 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00	34.9	27.3	33.3	27.3	29.3	27.3	34.2	27.3	27.5	27.3	28.2	27.3	33.5	27.3	34.3	27.3	35.3	27.3	35.8	27.3	(Sunny/Cloudy, 32/22)
12:00:00	53.6	33.6	53.8	33.6	54.8	33.6	55.4	33.6	54.8	33.6	56.3	33.6	51.1	33.6	52.4	33.6	55.3	33.6	54.4	33.6	
17:00:00	31.9	24.0	30.0	24.0	28.1	24.0	24.2	24.0	28.2	24.0	27.7	24.0	30.9	24.0	31.4	24.0	30.5	24.0	32.6	24.0	
22:00:00	26.7	24.3	26.9	24.3	28.7	24.3	25.6	24.3	25.2	24.3	26.0	24.3	26.3	24.3	30.4	24.3	28.5	24.3	25.4	24.3	
Thursday, 24 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					
17:00:00																					
22:00:00																					
Friday, 25 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					
17:00:00																					
22:00:00																					
Saturday, 26 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					
17:00:00																					
22:00:00																					
Sunday, 27 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					
17:00:00																					
22:00:00																					
Monday, 28 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					
17:00:00																					
22:00:00																					
Tuesday, 29 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no.3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00	32.7	26.3	30.5	26.3	27.5	26.3	31.7	26.3	25.9	26.3	27.0	26.3	33.4	26.3	31.7	26.3	30.2	26.3	31.9	26.3	(Sunny, 33/22)
12:00:00	57.6	35.8	58.1	35.8	55.4	35.8	56.7	35.8	59.8	35.8	56.4	35.8	57.7	35.8	61.0	35.8	59.8	35.8	57.2	35.8	
17:00:00	45.0	28.3	49.5	28.3	52.2	28.3	28.6	28.3	46.0	28.3	44.5	28.3	46.5	28.3	39.2	28.3	45.8	28.3	42.9	28.3	
22:00:00	29.2	26.7	32.6	26.7	30.8	26.7	28.3	26.7	28.6	26.7	29.1	26.7	27.5	26.7	28.8	26.7	28.3	26.7	27.0	26.7	
Wednesday, 30 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no.3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00	33.6	24.5	33.2	24.5	31.3	24.5	30.1	24.5	29.4	24.5	28.3	24.5	32.6	24.5	31.9	24.5	30.8	24.5	32.2	24.5	(Sunny/Cloudy, 34/23)
12:00:00	55.8	35.5	56.3	35.5	59.1	35.5	56.6	35.5	56.6	35.5	57.4	35.5	55.0	35.5	58.9	35.5	58.1	35.5	58.3	35.5	
17:00:00	37.0	29.0	33.7	29.0	34.8	29.0	29.5	29.0	29.6	29.0	29.0	29.0	32.0	29.0	33.7	29.0	32.8	29.0	32.8	29.0	
22:00:00	30.1	27.3	32.0	27.3	32.3	27.3	33.0	27.3	28.9	27.3	28.7	27.3	26.4	27.3	28.1	27.3	30.2	27.3	29.5	27.3	
Thursday, 31 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no.3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00	30.0	25.1	30.1	25.1	29.3	25.1	28.1	25.1	27.3	25.1	28.2	25.1	27.6	25.1	-	25.1	29.0	25.1	-	25.1	(Sunny, 37/21)
12:00:00	61.3	45.6	60.8	45.6	58.4	45.6	63.2	45.6	64.6	45.6	62.9	45.6	60.8	45.6	60.3	45.6	63.5	45.6	62.6	45.6	
17:00:00	46.7	37.6	48.8	37.6	49.0	37.6	43.8	37.6	45.1	37.6	44.2	37.6	47.9	37.6	42.9	37.6	48.7	37.6	48.6	37.6	
22:00:00	34.4	30.2	34.6	30.2	33.8	30.2	35.2	30.2	31.5	30.2	31.9	30.2	33.0	30.2	31.6	30.2	33.0	30.2	34.5	30.2	

Site 3 – Newcastle Interchange

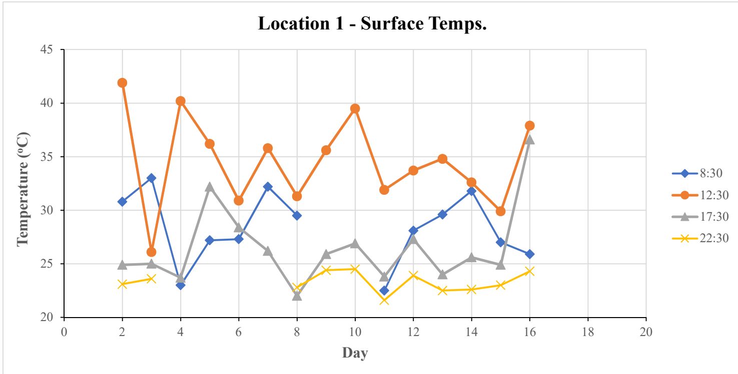
SCROLL FOR ALL SITES →

LOCATION 1 (Wood)





Ambient	
Time	**Average Temp. (°C)**
8:30:00	26.2
12:30:00	33.6
17:30:00	28.3
22:30:00	26.6



Surface	
Time	**Average Temp. (°C)**
8:30:00	28.3
12:30:00	34.6
17:30:00	26.5
22:30:00	23.3

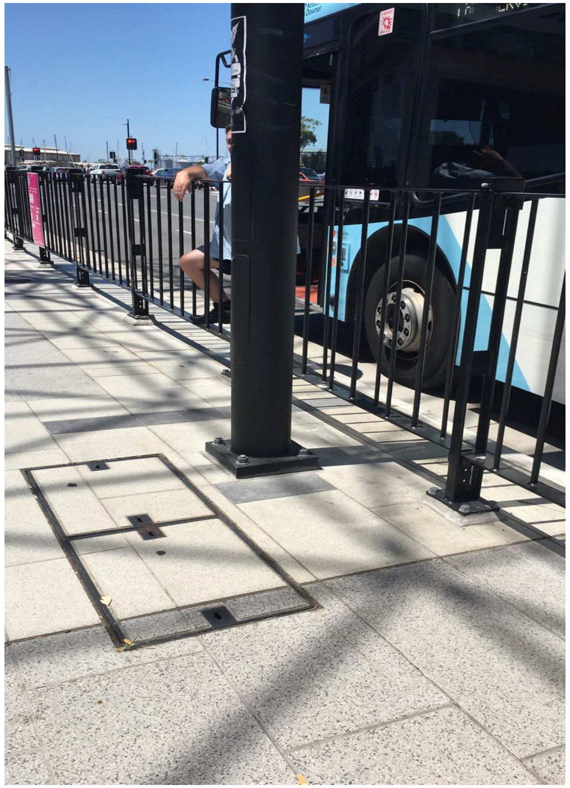
Ambient (All of Newcastle Int. Sites)

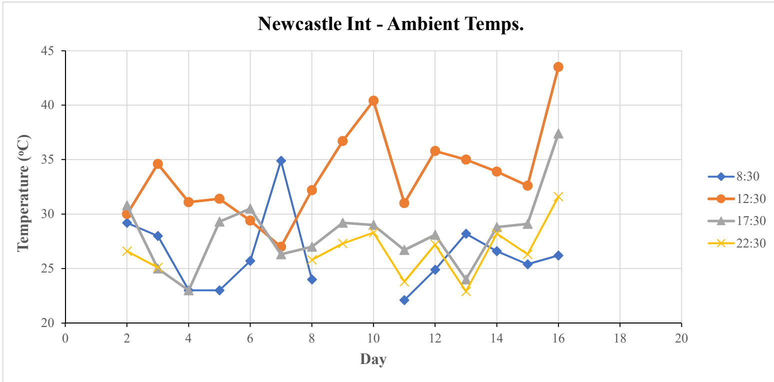
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:30:00	12:30:00	17:30:00	22:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	29.2	30.0	30.8	26.6
Jan-09	3	30, 22	28.0	34.6	25.0	25.1
Jan-10	4	27, 21	23.0	31.1	23.0	
Jan-11	5	26, 19	23.0	31.4	29.3	
Jan-12	6	33, 20	25.7	29.4	30.5	
Jan-13	7	31, 21	34.9	27.0	26.3	
Jan-14	8	29, 20	24.0	32.2	27.0	25.8
Jan-15	9	34, 21		36.7	29.2	27.3
Jan-16	10	35, 22		40.4	29.0	28.3
Jan-21	11	29, 21	22.1	31.0	26.7	23.8
Jan-22	12	33, 22	24.9	35.8	28.1	27.2
Jan-23	13	32, 22	28.2	35.0	24.0	22.9
Jan-29	14	33, 22	26.6	33.9	28.8	28.2
Jan-30	15	34, 23	25.4	32.6	29.1	26.3
Jan-31	16	37, 21	26.2	43.5	37.4	31.6
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			26.2	33.6	28.3	26.6

Surface (Location 1)

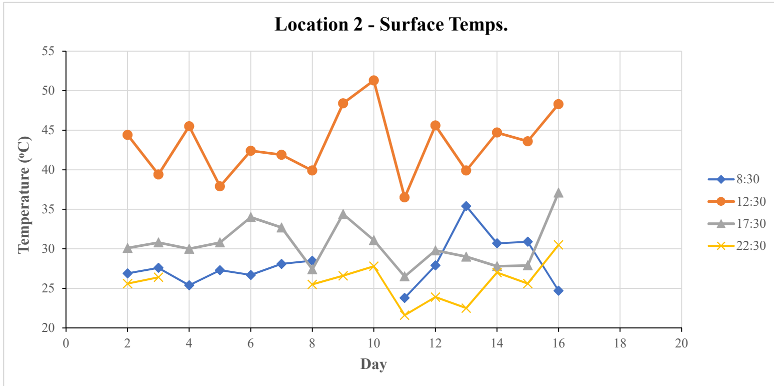
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:30:00	12:30:00	17:30:00	22:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	30.8	41.9	24.9	23.1
Jan-09	3	30, 22	33.0	26.1	25.0	23.6
Jan-10	4	27, 21	23.0	40.2	23.7	
Jan-11	5	26, 19	27.2	36.2	32.2	
Jan-12	6	33, 20	27.3	30.9	28.4	
Jan-13	7	31, 21	32.2	35.8	26.2	
Jan-14	8	29, 20	29.5	31.3	22.0	22.8
Jan-15	9	34, 21		35.6	25.9	24.4
Jan-16	10	35, 22		39.5	26.9	24.5
Jan-21	11	29, 21	22.5	31.9	23.8	21.6
Jan-22	12	33, 22	28.1	33.7	27.3	23.9
Jan-23	13	32, 22	29.6	34.8	24.0	22.5
Jan-29	14	33, 22	31.8	32.6	25.6	22.6
Jan-30	15	34, 23	27.0	29.9	24.9	23.0
Jan-31	16	37, 21	25.9	37.9	36.6	24.3
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			28.3	34.6	26.5	23.3

LOCATION 2 (Bluestone)





Ambient	
Time	Average Temp. (°C)
8:30:00	26.2
12:30:00	33.6
17:30:00	28.3
22:30:00	26.6

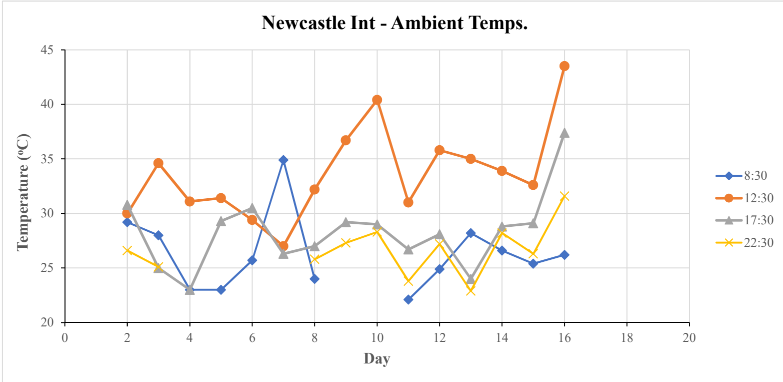


Surface	
Time	Average Temp. (°C)
8:30:00	28.0
12:30:00	43.3
17:30:00	30.6
22:30:00	25.7

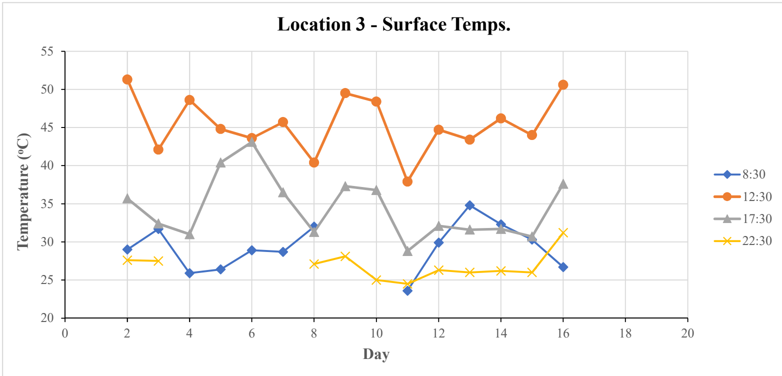
Ambient (All of Newcastle Int. Sites)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:30:00	12:30:00	17:30:00	22:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	29.2	30.0	30.8	26.6
Jan-09	3	30, 22	28.0	34.6	25.0	25.1
Jan-10	4	27, 21	23.0	31.1	23.0	
Jan-11	5	26, 19	23.0	31.4	29.3	
Jan-12	6	33, 20	25.7	29.4	30.5	
Jan-13	7	31, 21	34.9	27.0	26.3	
Jan-14	8	29, 20	24.0	32.2	27.0	25.8
Jan-15	9	34, 21		36.7	29.2	27.3
Jan-16	10	35, 22		40.4	29.0	28.3
Jan-21	11	29, 21	22.1	31.0	26.7	23.8
Jan-22	12	33, 22	24.9	35.8	28.1	27.2
Jan-23	13	32, 22	28.2	35.0	24.0	22.9
Jan-29	14	33, 22	26.6	33.9	28.8	28.2
Jan-30	15	34, 23	25.4	32.6	29.1	26.3
Jan-31	16	37, 21	26.2	43.5	37.4	31.6
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			26.2	33.6	28.3	26.6

Surface (Location 2)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:30:00	12:30:00	17:30:00	22:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	26.9	44.4	30.1	25.6
Jan-09	3	30, 22	27.6	39.4	30.8	26.4
Jan-10	4	27, 21	25.4	45.5	30.0	
Jan-11	5	26, 19	27.3	37.9	30.8	
Jan-12	6	33, 20	26.7	42.4	34.0	
Jan-13	7	31, 21	28.1	41.9	32.7	
Jan-14	8	29, 20	28.5	39.9	27.4	25.5
Jan-15	9	34, 21		48.4	34.4	26.6
Jan-16	10	35, 22		51.3	31.1	27.8
Jan-21	11	29, 21	23.8	36.5	26.5	21.6
Jan-22	12	33, 22	27.9	45.6	29.8	23.9
Jan-23	13	32, 22	35.4	39.9	29.0	22.5
Jan-29	14	33, 22	30.7	44.7	27.8	27.0
Jan-30	15	34, 23	30.9	43.6	27.9	25.6
Jan-31	16	37, 21	24.7	48.3	37.1	30.5
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			28.0	43.3	30.6	25.7

LOCATION 3 (Concrete)



Ambient	
Time	Average Temp. (°C)
8:30:00	26.2
12:30:00	33.6
17:30:00	28.3
22:30:00	26.6

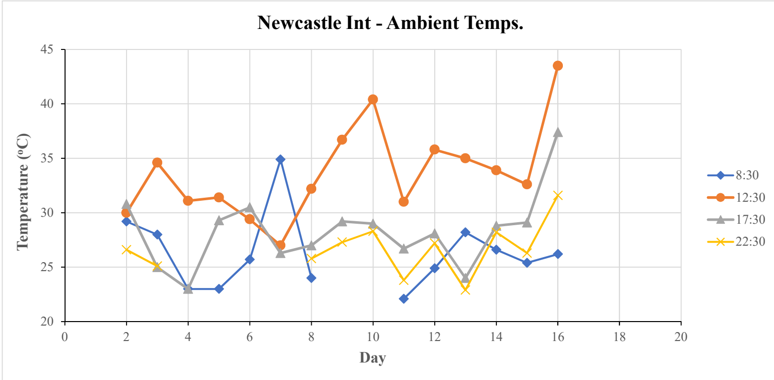


Surface	
Time	Average Temp. (°C)
8:30:00	29.2
12:30:00	45.4
17:30:00	34.5
22:30:00	26.9

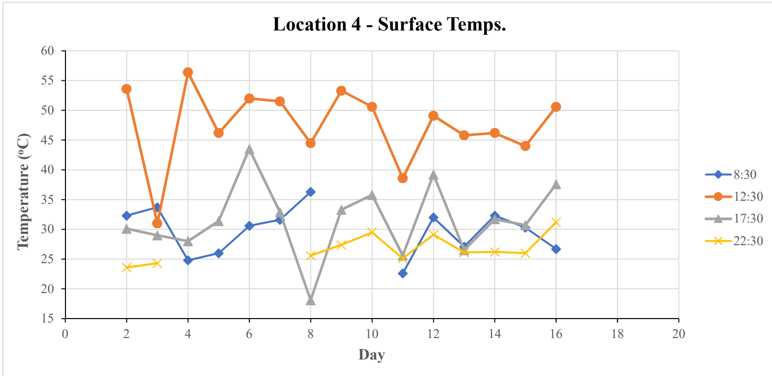
Ambient (All of Newcastle Int. Sites)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:30:00	12:30:00	17:30:00	22:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	29.2	30.0	30.8	26.6
Jan-09	3	30, 22	28.0	34.6	25.0	25.1
Jan-10	4	27, 21	23.0	31.1	23.0	
Jan-11	5	26, 19	23.0	31.4	29.3	
Jan-12	6	33, 20	25.7	29.4	30.5	
Jan-13	7	31, 21	34.9	27.0	26.3	
Jan-14	8	29, 20	24.0	32.2	27.0	25.8
Jan-15	9	34, 21		36.7	29.2	27.3
Jan-16	10	35, 22		40.4	29.0	28.3
Jan-21	11	29, 21	22.1	31.0	26.7	23.8
Jan-22	12	33, 22	24.9	35.8	28.1	27.2
Jan-23	13	32, 22	28.2	35.0	24.0	22.9
Jan-29	14	33, 22	26.6	33.9	28.8	28.2
Jan-30	15	34, 23	25.4	32.6	29.1	26.3
Jan-31	16	37, 21	26.2	43.5	37.4	31.6
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			26.2	33.6	28.3	26.6

Surface (Location 3)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:30:00	12:30:00	17:30:00	22:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	29.0	51.3	35.7	27.6
Jan-09	3	30, 22	31.7	42.1	32.4	27.5
Jan-10	4	27, 21	25.9	48.6	31.0	
Jan-11	5	26, 19	26.4	44.8	40.4	
Jan-12	6	33, 20	28.9	43.6	43.1	
Jan-13	7	31, 21	28.7	45.7	36.5	
Jan-14	8	29, 20	32.0	40.4	31.3	27.1
Jan-15	9	34, 21		49.5	37.3	28.1
Jan-16	10	35, 22		48.4	36.8	25.0
Jan-21	11	29, 21	23.6	37.9	28.8	24.5
Jan-22	12	33, 22	29.9	44.7	32.1	26.3
Jan-23	13	32, 22	34.8	43.4	31.6	26.0
Jan-29	14	33, 22	32.3	46.2	31.7	26.2
Jan-30	15	34, 23	30.3	44.0	30.7	26.0
Jan-31	16	37, 21	26.7	50.6	37.6	31.2
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			29.2	45.4	34.5	26.9

LOCATION 4 (Mulch)



Ambient	
Time	Average Temp. (°C)
8:30:00	26.2
12:30:00	33.6
17:30:00	28.3
22:30:00	26.6



Surface	
Time	Average Temp. (°C)
8:30:00	29.7
12:30:00	47.6
17:30:00	31.6
22:30:00	26.7

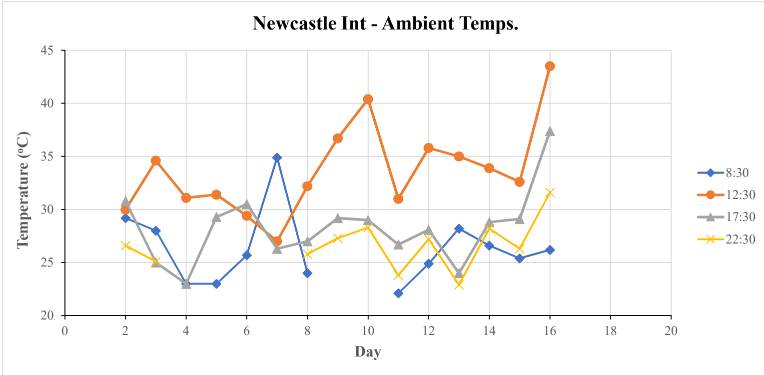
Ambient (All of Newcastle Int. Sites)

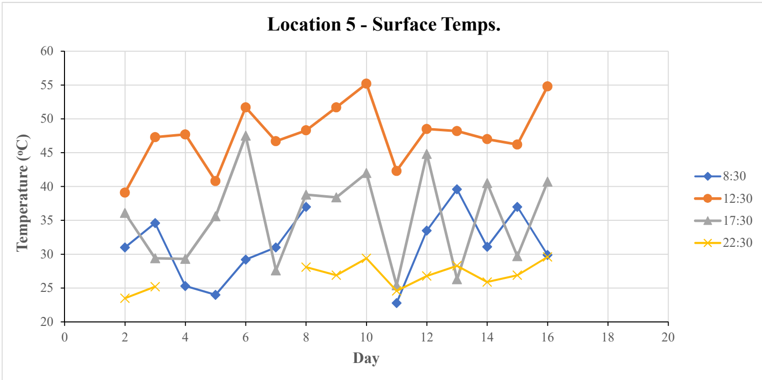
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:30:00	12:30:00	17:30:00	22:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	29.2	30.0	30.8	26.6
Jan-09	3	30, 22	28.0	34.6	25.0	25.1
Jan-10	4	27, 21	23.0	31.1	23.0	
Jan-11	5	26, 19	23.0	31.4	29.3	
Jan-12	6	33, 20	25.7	29.4	30.5	
Jan-13	7	31, 21	34.9	27.0	26.3	
Jan-14	8	29, 20	24.0	32.2	27.0	25.8
Jan-15	9	34, 21		36.7	29.2	27.3
Jan-16	10	35, 22		40.4	29.0	28.3
Jan-21	11	29, 21	22.1	31.0	26.7	23.8
Jan-22	12	33, 22	24.9	35.8	28.1	27.2
Jan-23	13	32, 22	28.2	35.0	24.0	22.9
Jan-29	14	33, 22	26.6	33.9	28.8	28.2
Jan-30	15	34, 23	25.4	32.6	29.1	26.3
Jan-31	16	37, 21	26.2	43.5	37.4	31.6
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			**26.2**	**33.6**	**28.3**	**26.6**

Surface (Location 4)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:30:00	12:30:00	17:30:00	22:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	32.3	53.6	30.1	23.6
Jan-09	3	30, 22	33.7	31.0	29.0	24.3
Jan-10	4	27, 21	24.8	56.4	28.0	
Jan-11	5	26, 19	26.0	46.2	31.4	
Jan-12	6	33, 20	30.6	52.0	43.5	
Jan-13	7	31, 21	31.6	51.5	32.9	
Jan-14	8	29, 20	36.3	44.5	18.1	25.6
Jan-15	9	34, 21		53.3	33.3	27.4
Jan-16	10	35, 22		50.6	35.8	29.5
Jan-21	11	29, 21	22.6	38.6	25.6	25.1
Jan-22	12	33, 22	32.0	49.1	39.2	29.1
Jan-23	13	32, 22	27.1	45.8	26.5	26.1
Jan-29	14	33, 22	32.3	46.2	31.7	26.2
Jan-30	15	34, 23	30.3	44.0	30.7	26.0
Jan-31	16	37, 21	26.7	50.6	37.6	31.2
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			**29.7**	**47.6**	**31.6**	**26.7**

LOCATION 5 (Mulch)





Ambient	
Time	Average Temp. (°C)
8:30:00	26.2
12:30:00	33.6
17:30:00	28.3
22:30:00	26.6

Surface	
Time	Average Temp. (°C)
8:30:00	31.2
12:30:00	47.7
17:30:00	35.5
22:30:00	26.8

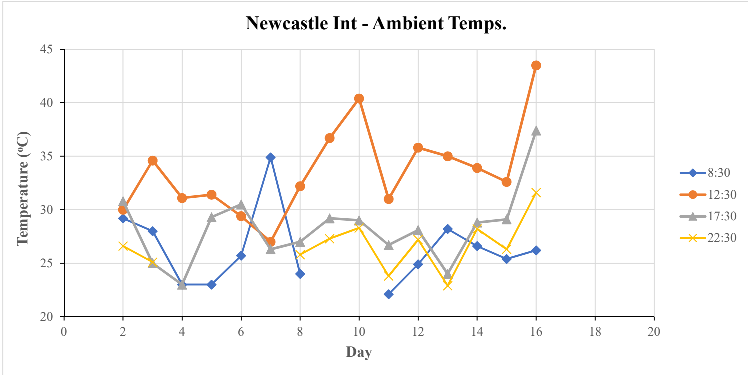
Ambient (All of Newcastle Int. Sites)

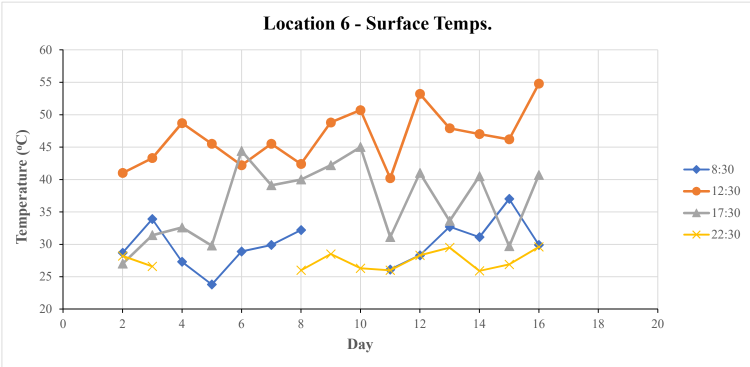
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:30:00	12:30:00	17:30:00	22:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	29.2	30.0	30.8	26.6
Jan-09	3	30, 22	28.0	34.6	25.0	25.1
Jan-10	4	27, 21	23.0	31.1	23.0	
Jan-11	5	26, 19	23.0	31.4	29.3	
Jan-12	6	33, 20	25.7	29.4	30.5	
Jan-13	7	31, 21	34.9	27.0	26.3	
Jan-14	8	29, 20	24.0	32.2	27.0	25.8
Jan-15	9	34, 21		36.7	29.2	27.3
Jan-16	10	35, 22		40.4	29.0	28.3
Jan-21	11	29, 21	22.1	31.0	26.7	23.8
Jan-22	12	33, 22	24.9	35.8	28.1	27.2
Jan-23	13	32, 22	28.2	35.0	24.0	22.9
Jan-29	14	33, 22	26.6	33.9	28.8	28.2
Jan-30	15	34, 23	25.4	32.6	29.1	26.3
Jan-31	16	37, 21	26.2	43.5	37.4	31.6
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			26.2	33.6	28.3	26.6

Surface (Location 5)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:30:00	12:30:00	17:30:00	22:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	31.0	39.1	36.1	23.5
Jan-09	3	30, 22	34.6	47.3	29.4	25.2
Jan-10	4	27, 21	25.3	47.7	29.3	
Jan-11	5	26, 19	24.0	40.8	35.6	
Jan-12	6	33, 20	29.2	51.7	47.5	
Jan-13	7	31, 21	31.0	46.7	27.6	
Jan-14	8	29, 20	37.0	48.3	38.8	28.1
Jan-15	9	34, 21		51.7	38.4	26.9
Jan-16	10	35, 22		55.2	42.0	29.4
Jan-21	11	29, 21	22.8	42.3	25.4	24.6
Jan-22	12	33, 22	33.5	48.5	44.8	26.8
Jan-23	13	32, 22	39.6	48.2	26.3	28.3
Jan-29	14	33, 22	31.1	47.0	40.5	25.9
Jan-30	15	34, 23	37.0	46.2	29.7	26.9
Jan-31	16	37, 21	29.9	54.8	40.7	29.6
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			31.2	47.7	35.5	26.8

LOCATION 6 (Concrete)





Ambient	
Time	**Average Temp. (°C)**
8:30:00	26.2
12:30:00	33.6
17:30:00	28.3
22:30:00	26.6

Surface	
Time	**Average Temp. (°C)**
8:30:00	30.0
12:30:00	46.5
17:30:00	36.5
22:30:00	27.4

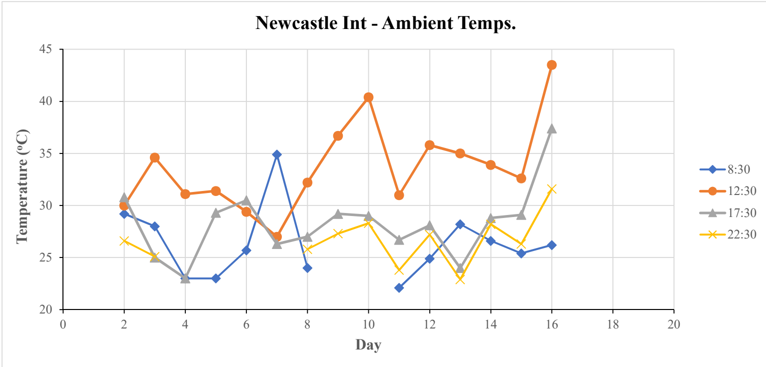
Ambient (All of Newcastle Int. Sites)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:30:00	12:30:00	17:30:00	22:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	29.2	30.0	30.8	26.6
Jan-09	3	30, 22	28.0	34.6	25.0	25.1
Jan-10	4	27, 21	23.0	31.1	23.0	
Jan-11	5	26, 19	23.0	31.4	29.3	
Jan-12	6	33, 20	25.7	29.4	30.5	
Jan-13	7	31, 21	34.9	27.0	26.3	
Jan-14	8	29, 20	24.0	32.2	27.0	25.8
Jan-15	9	34, 21		36.7	29.2	27.3
Jan-16	10	35, 22		40.4	29.0	28.3
Jan-21	11	29, 21	22.1	31.0	26.7	23.8
Jan-22	12	33, 22	24.9	35.8	28.1	27.2
Jan-23	13	32, 22	28.2	35.0	24.0	22.9
Jan-29	14	33, 22	26.6	33.9	28.8	28.2
Jan-30	15	34, 23	25.4	32.6	29.1	26.3
Jan-31	16	37, 21	26.2	43.5	37.4	31.6
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			**26.2**	**33.6**	**28.3**	**26.6**

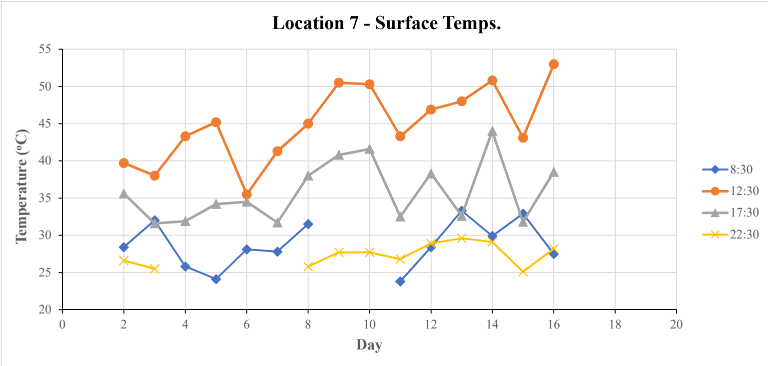
Surface (Location 6)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:30:00	12:30:00	17:30:00	22:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	28.7	41.0	27.0	28.2
Jan-09	3	30, 22	33.9	43.3	31.4	26.6
Jan-10	4	27, 21	27.3	48.7	32.6	
Jan-11	5	26, 19	23.8	45.5	29.8	
Jan-12	6	33, 20	28.9	42.2	44.4	
Jan-13	7	31, 21	29.9	45.5	39.1	
Jan-14	8	29, 20	32.2	42.4	40.0	26.0
Jan-15	9	34, 21		48.8	42.2	28.5
Jan-16	10	35, 22		50.7	45.0	26.3
Jan-21	11	29, 21	26.1	40.2	31.1	26.0
Jan-22	12	33, 22	28.3	53.2	41.0	28.3
Jan-23	13	32, 22	32.7	47.9	33.6	29.5
Jan-29	14	33, 22	31.1	47.0	40.5	25.9
Jan-30	15	34, 23	37.0	46.2	29.7	26.9
Jan-31	16	37, 21	29.9	54.8	40.7	29.6
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			**30.0**	**46.5**	**36.5**	**27.4**

LOCATION 7 (Concrete)



Ambient	
Time	**Average Temp. (°C)**
8:30:00	26.2
12:30:00	33.6
17:30:00	28.3
22:30:00	26.6

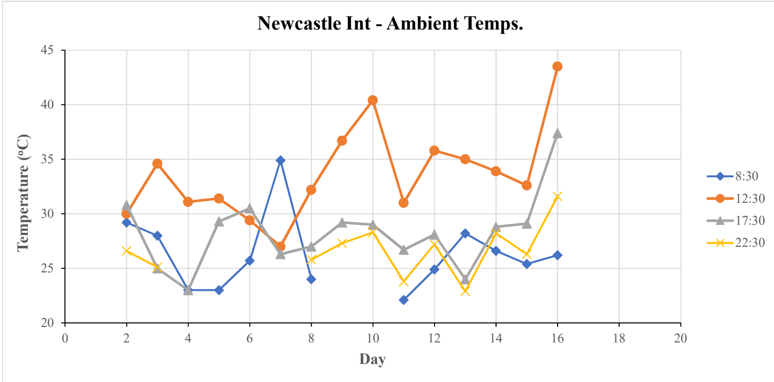


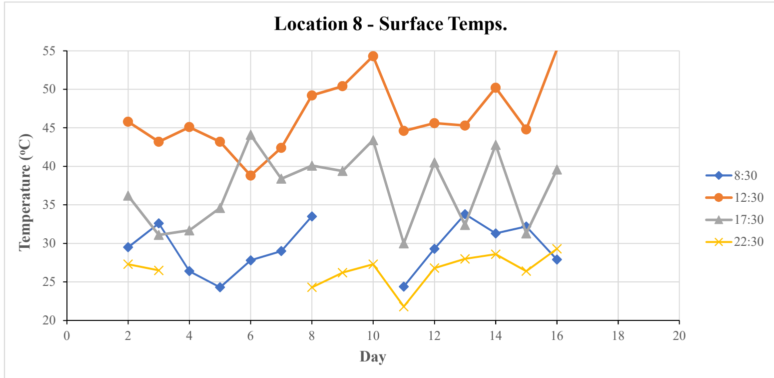
Surface	
Time	**Average Temp. (°C)**
8:30:00	28.7
12:30:00	44.9
17:30:00	35.8
22:30:00	27.4

Ambient (All of Newcastle Int. Sites)						
Date	**Day**	**Weather Forecast (Max, Min) (°C)**	**Time/Ambient Temp. (°C)**			
			8:30:00	**12:30:00**	**17:30:00**	**22:30:00**
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	29.2	30.0	30.8	26.6
Jan-09	3	30, 22	28.0	34.6	25.0	25.1
Jan-10	4	27, 21	23.0	31.1	23.0	
Jan-11	5	26, 19	23.0	31.4	29.3	
Jan-12	6	33, 20	25.7	29.4	30.5	
Jan-13	7	31, 21	34.9	27.0	26.3	
Jan-14	8	29, 20	24.0	32.2	27.0	25.8
Jan-15	9	34, 21		36.7	29.2	27.3
Jan-16	10	35, 22		40.4	29.0	28.3
Jan-21	11	29, 21	22.1	31.0	26.7	23.8
Jan-22	12	33, 22	24.9	35.8	28.1	27.2
Jan-23	13	32, 22	28.2	35.0	24.0	22.9
Jan-29	14	33, 22	26.6	33.9	28.8	28.2
Jan-30	15	34, 23	25.4	32.6	29.1	26.3
Jan-31	16	37, 21	26.2	43.5	37.4	31.6
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			**26.2**	**33.6**	**28.3**	**26.6**

Surface (Location 7)						
Date	**Day**	**Weather Forecast (Max, Min) (°C)**	**Time/Surface Temp. (°C)**			
			8:30:00	**12:30:00**	**17:30:00**	**22:30:00**
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	28.4	39.7	35.6	26.6
Jan-09	3	30, 22	32.0	38.0	31.6	25.5
Jan-10	4	27, 21	25.8	43.3	31.9	
Jan-11	5	26, 19	24.1	45.2	34.2	
Jan-12	6	33, 20	28.1	35.5	34.5	
Jan-13	7	31, 21	27.8	41.3	31.7	
Jan-14	8	29, 20	31.5	45.0	38.0	25.8
Jan-15	9	34, 21		50.5	40.8	27.7
Jan-16	10	35, 22		50.3	41.6	27.7
Jan-21	11	29, 21	23.8	43.3	32.5	26.8
Jan-22	12	33, 22	28.4	46.9	38.3	28.9
Jan-23	13	32, 22	33.3	48.0	32.6	29.6
Jan-29	14	33, 22	29.9	50.8	44.0	29.1
Jan-30	15	34, 23	32.9	43.1	31.8	25.1
Jan-31	16	37, 21	27.5	53.0	38.5	28.2
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			**28.7**	**44.9**	**35.8**	**27.4**

LOCATION 8 (Concrete)





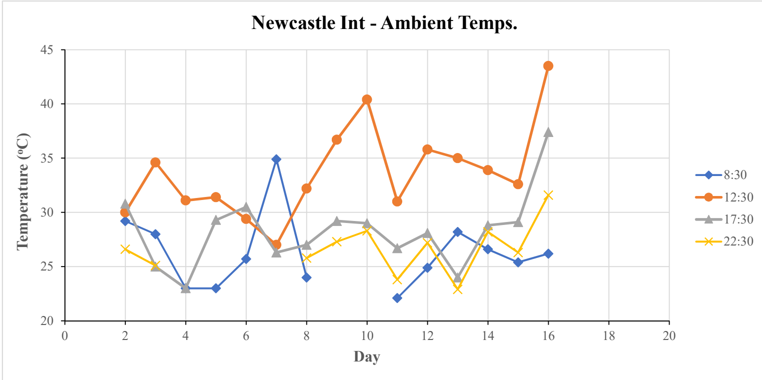
Ambient	
Time	Average Temp. (°C)
8:30:00	26.2
12:30:00	33.6
17:30:00	28.3
22:30:00	26.6

Surface	
Time	Average Temp. (°C)
8:30:00	29.4
12:30:00	46.5
17:30:00	37.0
22:30:00	26.6

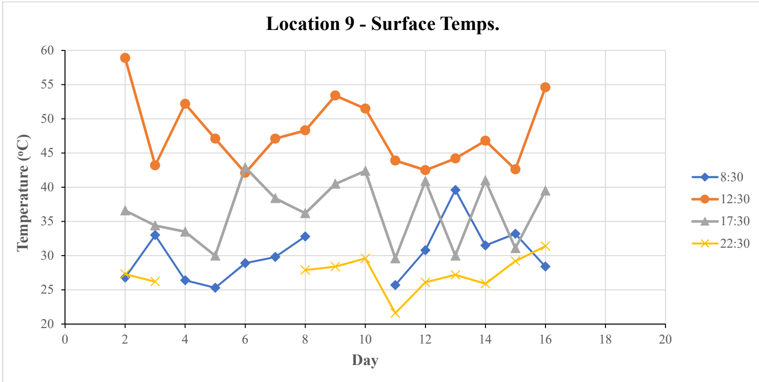
Ambient (All of Newcastle Int. Sites)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:30:00	12:30:00	17:30:00	22:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	29.2	30.0	30.8	26.6
Jan-09	3	30, 22	28.0	34.6	25.0	25.1
Jan-10	4	27, 21	23.0	31.1	23.0	
Jan-11	5	26, 19	23.0	31.4	29.3	
Jan-12	6	33, 20	25.7	29.4	30.5	
Jan-13	7	31, 21	34.9	27.0	26.3	
Jan-14	8	29, 20	24.0	32.2	27.0	25.8
Jan-15	9	34, 21		36.7	29.2	27.3
Jan-16	10	35, 22		40.4	29.0	28.3
Jan-21	11	29, 21	22.1	31.0	26.7	23.8
Jan-22	12	33, 22	24.9	35.8	28.1	27.2
Jan-23	13	32, 22	28.2	35.0	24.0	22.9
Jan-29	14	33, 22	26.6	33.9	28.8	28.2
Jan-30	15	34, 23	25.4	32.6	29.1	26.3
Jan-31	16	37, 21	26.2	43.5	37.4	31.6
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			**26.2**	**33.6**	**28.3**	**26.6**

Surface (Location 8)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:30:00	12:30:00	17:30:00	22:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	29.5	45.8	36.2	27.3
Jan-09	3	30, 22	32.6	43.2	31.1	26.5
Jan-10	4	27, 21	26.4	45.1	31.7	
Jan-11	5	26, 19	24.3	43.2	34.6	
Jan-12	6	33, 20	27.8	38.8	44.1	
Jan-13	7	31, 21	29.0	42.4	38.4	
Jan-14	8	29, 20	33.5	49.2	40.1	24.3
Jan-15	9	34, 21		50.4	39.4	26.2
Jan-16	10	35, 22		54.3	43.4	27.3
Jan-21	11	29, 21	24.4	44.6	30.0	21.8
Jan-22	12	33, 22	29.3	45.6	40.5	26.8
Jan-23	13	32, 22	33.8	45.3	32.4	28.0
Jan-29	14	33, 22	31.3	50.2	42.8	28.6
Jan-30	15	34, 23	32.2	44.8	31.3	26.4
Jan-31	16	37, 21	27.9	55.2	39.6	29.3
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			**29.4**	**46.5**	**37.0**	**26.6**

LOCATION 9 (Concrete)



Ambient	
Time	Average Temp. (°C)
8:30:00	26.2
12:30:00	33.6
17:30:00	28.3
22:30:00	26.6



Surface	
Time	Average Temp. (°C)
8:30:00	30.2
12:30:00	47.9
17:30:00	36.5
22:30:00	27.3

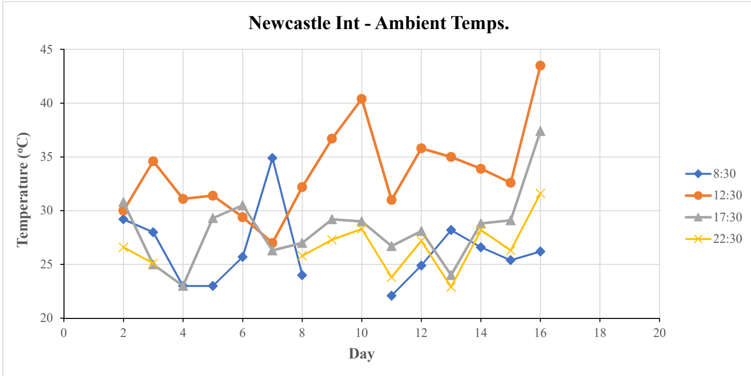
Ambient (All of Newcastle Int. Sites)

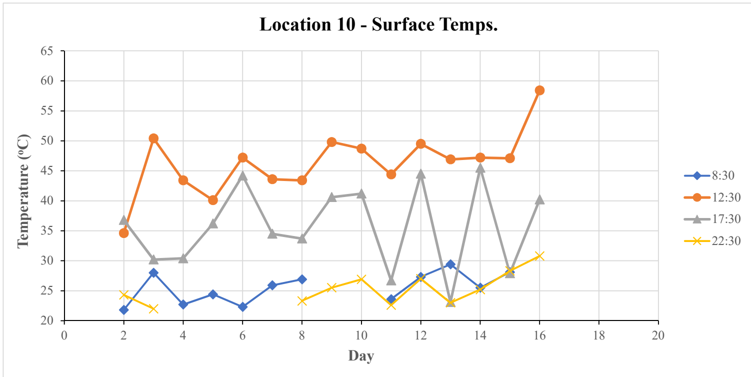
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:30:00	12:30:00	17:30:00	22:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	29.2	30.0	30.8	26.6
Jan-09	3	30, 22	28.0	34.6	25.0	25.1
Jan-10	4	27, 21	23.0	31.1	23.0	
Jan-11	5	26, 19	23.0	31.4	29.3	
Jan-12	6	33, 20	25.7	29.4	30.5	
Jan-13	7	31, 21	34.9	27.0	26.3	
Jan-14	8	29, 20	24.0	32.2	27.0	25.8
Jan-15	9	34, 21		36.7	29.2	27.3
Jan-16	10	35, 22		40.4	29.0	28.3
Jan-21	11	29, 21	22.1	31.0	26.7	23.8
Jan-22	12	33, 22	24.9	35.8	28.1	27.2
Jan-23	13	32, 22	28.2	35.0	24.0	22.9
Jan-29	14	33, 22	26.6	33.9	28.8	28.2
Jan-30	15	34, 23	25.4	32.6	29.1	26.3
Jan-31	16	37, 21	26.2	43.5	37.4	31.6
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			26.2	33.6	28.3	26.6

Surface (Location 9)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:30:00	12:30:00	17:30:00	22:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	26.8	58.9	36.6	27.3
Jan-09	3	30, 22	33.0	43.2	34.4	26.2
Jan-10	4	27, 21	26.4	52.2	33.5	
Jan-11	5	26, 19	25.3	47.1	30.0	
Jan-12	6	33, 20	28.9	42.1	42.9	
Jan-13	7	31, 21	29.8	47.1	38.4	
Jan-14	8	29, 20	32.8	48.3	36.2	27.9
Jan-15	9	34, 21		53.4	40.5	28.4
Jan-16	10	35, 22		51.5	42.4	29.6
Jan-21	11	29, 21	25.7	43.9	29.6	21.6
Jan-22	12	33, 22	30.8	42.5	40.9	26.1
Jan-23	13	32, 22	39.6	44.2	30.0	27.2
Jan-29	14	33, 22	31.5	46.8	41.0	25.9
Jan-30	15	34, 23	33.2	42.6	31.1	29.2
Jan-31	16	37, 21	28.4	54.6	39.5	31.4
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			30.2	47.9	36.5	27.3

LOCATION 10 (Mulch)





Ambient	
Time	Average Temp. (°C)
8:30:00	26.2
12:30:00	33.6
17:30:00	28.3
22:30:00	26.6

Surface	
Time	Average Temp. (°C)
8:30:00	25.5
12:30:00	46.3
17:30:00	35.7
22:30:00	25.4

Ambient (All of Newcastle Int. Sites)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:30:00	12:30:00	17:30:00	22:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	29.2	30.0	30.8	26.6
Jan-09	3	30, 22	28.0	34.6	25.0	25.1
Jan-10	4	27, 21	23.0	31.1	23.0	
Jan-11	5	26, 19	23.0	31.4	29.3	
Jan-12	6	33, 20	25.7	29.4	30.5	
Jan-13	7	31, 21	34.9	27.0	26.3	
Jan-14	8	29, 20	24.0	32.2	27.0	25.8
Jan-15	9	34, 21		36.7	29.2	27.3
Jan-16	10	35, 22		40.4	29.0	28.3
Jan-21	11	29, 21	22.1	31.0	26.7	23.8
Jan-22	12	33, 22	24.9	35.8	28.1	27.2
Jan-23	13	32, 22	28.2	35.0	24.0	22.9
Jan-29	14	33, 22	26.6	33.9	28.8	28.2
Jan-30	15	34, 23	25.4	32.6	29.1	26.3
Jan-31	16	37, 21	26.2	43.5	37.4	31.6
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			**26.2**	**33.6**	**28.3**	**26.6**

Surface (Location 10)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:30:00	12:30:00	17:30:00	22:30:00
Jan-07	1	Excluded (Rain)				
Jan-08	2	28, 21	21.8	34.6	36.8	24.3
Jan-09	3	30, 22	28.0	50.4	30.2	22.0
Jan-10	4	27, 21	22.7	43.4	30.4	
Jan-11	5	26, 19	24.4	40.1	36.2	
Jan-12	6	33, 20	22.3	47.2	44.2	
Jan-13	7	31, 21	25.9	43.6	34.5	
Jan-14	8	29, 20	26.9	43.4	33.7	23.3
Jan-15	9	34, 21		49.8	40.6	25.5
Jan-16	10	35, 22		48.7	41.2	26.9
Jan-21	11	29, 21	23.6	44.4	26.7	22.6
Jan-22	12	33, 22	27.3	49.5	44.5	27.0
Jan-23	13	32, 22	29.4	46.9	23.1	23.0
Jan-29	14	33, 22	25.5	47.2	45.5	25.2
Jan-30	15	34, 23	28.1	47.1	27.9	28.3
Jan-31	16	37, 21		58.4	40.2	30.8
Feb-04	17	Data Collection Concluded				
Feb-05	18					
Feb-06	19					
Average Temp. (°C)			**25.5**	**46.3**	**35.7**	**25.4**

Site 3 – Newcastle Interchange

Date	Temperature Readings (°C)																				
Monday, 7 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface (Plywood)	Air	Surface (Bluestone)	Air	Surface (Concrete)	Air	Surface (Mulch)	Air	Surface (Mulch)	Air	Surface (Concrete)	Air	Surface (Concrete)	Air	Surface (Concrete)	Air	Surface (Concrete)	Air	Surface (Mulch)	Air	
08:30:00	19.9	21.8	22.4	21.8	22.3	21.8	21.9	21.8	21.5	21.8	21.8	21.8	20.5	21.8	21.1	21.8	21.4	21.8	20.6	21.8	(Rainy day)
12:30:00	23.4	28.0	30.6	28.0	30.1	28.0	28.9	28.0	31.1	28.0	31.1	28.0	29.1	28.0	31.0	28.0	32.6	28.0	32.3	28.0	
17:30:00	23.6	25.8	29.2	25.8	30.3	25.8	23.5	25.8	23.8	25.8	27.2	25.8	25.4	25.8	26.1	25.8	26.3	25.8	22.8	25.8	
22:30:00	23.4	22.5	25.1	22.5	26.3	22.5	23.0	22.5	22.6	22.5	25.9	22.5	24.2	22.5	24.6	22.5	25.4	22.5	22.5	22.5	
Tuesday, 8 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00	30.8	29.2	26.9	29.2	29.0	29.2	32.3	29.2	31.0	29.2	28.7	29.2	28.4	29.2	29.5	29.2	26.8	29.2	21.8	29.2	(Sunny, 28/21)
12:30:00	41.9	30.0	44.4	30.0	51.3	30.0	53.6	30.0	39.1	30.0	41.0	30.0	39.7	30.0	45.8	30.0	58.9	30.0	34.6	30.0	
17:30:00	24.9	30.8	30.1	30.8	35.7	30.8	30.1	30.8	36.1	30.8	27.0	30.8	35.6	30.8	36.2	30.8	36.6	30.8	36.8	30.8	
22:30:00	23.1	26.6	25.6	26.6	27.6	26.6	23.6	26.6	23.5	26.6	28.2	26.6	26.6	26.6	27.3	26.6	27.3	26.6	24.3	26.6	
Wednesday, 9 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air		Air	Surface	Air	Surface	Air	
08:30:00	33.0	28.0	27.6	28.0	31.7	28.0	33.7	28.0	34.6	28.0	33.9	28.0	32.0	28.0	32.6	28.0	33.0	28.0	28.0	28.0	(Sunny, 30/22)
12:30:00	26.1	34.6	39.4	34.6	42.1	34.6	31.0	34.6	47.3	34.6	43.3	34.6	38.0	34.6	43.2	34.6	43.2	34.6	50.4	34.6	
17:30:00	25.0	25.0	30.8	25.0	32.4	25.0	29.0	25.0	29.4	25.0	31.4	25.0	31.6	25.0	31.1	25.0	34.4	25.0	30.2	25.0	
22:30:00	23.6	25.1	26.4	25.1	27.5	25.1	24.3	25.1	25.2	25.1	26.6	25.1	25.5	25.1	26.5	25.1	26.2	25.1	22.0	25.1	
Thursday, 10 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00	23.0	23.0	25.4	23.0	25.9	23.0	24.8	23.0	25.3	23.0	27.3	23.0	25.8	23.0	26.4	23.0	26.4	23.0	22.7	23.0	(Cloudy, 27/21)
12:30:00	40.2	31.1	45.5	31.1	48.6	31.1	56.4	31.1	47.7	31.1	48.7	31.1	43.3	31.1	45.1	31.1	52.2	31.1	43.4	31.1	
17:30:00	23.7	23.0	30.0	23.0	31.0	23.0	28.0	23.0	29.3	23.0	32.6	23.0	31.9	23.0	31.7	23.0	33.5	23.0	30.4	23.0	
22:30:00																					
Friday, 11 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00	27.2	23.0	27.3	23.0	26.4	23.0	26.0	23.0	24.0	23.0	23.8	23.0	24.1	23.0	24.3	23.0	25.3	23.0	24.4	23.0	(Cloudy, 26/19)
12:30:00	36.2	31.4	37.9	31.4	44.8	31.4	46.2	31.4	40.8	31.4	45.5	31.4	45.2	31.4	43.2	31.4	47.1	31.4	40.1	31.4	
17:30:00	32.2	29.3	30.8	29.3	40.4	29.3	31.4	29.3	35.6	29.3	29.8	29.3	34.2	29.3	34.6	29.3	30.0	29.3	36.2	29.3	
22:30:00																					
Saturday, 12 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00	27.3	25.7	26.7	25.7	28.9	25.7	30.6	25.7	29.2	25.7	28.9	25.7	28.1	25.7	27.8	25.7	28.9	25.7	22.3	25.7	(Sunny, 33/20)
12:30:00	30.9	29.4	42.4	29.4	43.6	29.4	52.0	29.4	51.7	29.4	42.2	29.4	35.5	29.4	38.8	29.4	42.1	29.4	47.2	29.4	
17:30:00	28.4	30.5	34.0	30.5	43.1	30.5	43.5	30.5	47.5	30.5	44.4	30.5	34.5	30.5	44.1	30.5	42.9	30.5	44.2	30.5	
22:30:00																					
Sunday, 13 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00	32.2	34.9	28.1	34.9	28.7	34.9	31.6	34.9	31.0	34.9	29.9	34.9	27.8	34.9	29.0	34.9	29.8	34.9	25.9	34.9	(Sunny, 31/21)
12:30:00	35.8	27.0	41.9	27.0	45.7	27.0	51.5	27.0	46.7	27.0	45.5	27.0	41.3	27.0	42.4	27.0	47.1	27.0	43.6	27.0	
17:30:00	26.2	26.3	32.7	26.3	36.5	26.3	32.9	26.3	27.6	26.3	39.1	26.3	31.7	26.3	38.4	26.3	38.4	26.3	34.5	26.3	
22:30:00																					
Monday, 14 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00	29.5	24.0	28.5	24.0	32.0	24.0	36.3	24.0	37.0	24.0	32.2	24.0	31.5	24.0	33.5	24.0	32.8	24.0	26.9	24.0	(Sunny/cloud, 29/20) (Did rain)
12:30:00	31.3	32.2	39.9	32.2	40.4	32.2	44.5	32.2	48.3	32.2	42.4	32.2	45.0	32.2	49.2	32.2	48.3	32.2	43.4	32.2	
17:30:00	22.0	27.0	27.4	27.0	31.3	27.0	18.1	27.0	38.8	27.0	40.0	27.0	38.0	27.0	40.1	27.0	36.2	27.0	33.7	27.0	
22:30:00	22.8	25.8	25.5	25.8	27.1	25.8	25.6	25.8	28.1	25.8	26.0	25.8	25.8	25.8	24.3	25.8	27.9	25.8	23.3	25.8	
Tuesday, 15 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(Sunny, 34/21)
12:30:00	35.6	36.7	48.4	36.7	49.5	36.7	53.3	36.7	51.7	36.7	48.8	36.7	50.5	36.7	50.4	36.7	53.4	36.7	49.8	36.7	
17:30:00	25.9	29.2	34.4	29.2	37.3	29.2	33.3	29.2	38.4	29.2	42.2	29.2	40.8	29.2	39.4	29.2	40.5	29.2	40.6	29.2	
22:30:00	24.4	27.3	26.6	27.3	28.1	27.3	27.4	27.3	26.9	27.3	28.5	27.3	27.7	27.3	26.2	27.3	28.4	27.3	25.5	27.3	
Wednesday, 16 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(Sunny, 35/22)
12:30:00	39.5	40.4	51.3	40.4	48.4	40.4	50.6	40.4	55.2	40.4	50.7	40.4	50.3	40.4	54.3	40.4	51.5	40.4	48.7	40.4	
17:30:00	26.9	29.0	31.1	29.0	36.8	29.0	35.8	29.0	42.0	29.0	45.0	29.0	41.6	29.0	43.4	29.0	42.4	29.0	41.2	29.0	
22:30:00	24.5	28.3	27.8	28.3	25.0	28.3	29.5	28.3	29.4	28.3	26.3	28.3	27.7	28.3	27.3	28.3	29.6	28.3	26.9	28.3	
Thursday, 17 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00																					
12:30:00																					
17:30:00																					
22:30:00																					
Friday, 18 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00																					
12:30:00																					
17:30:00																					
22:30:00																					

Saturday, 19 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00																					
12:30:00																					
17:30:00																					
22:30:00																					
Sunday, 20 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00																					
12:30:00																					
17:30:00																					
22:30:00																					
Monday, 21 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00	22.5	22.1	23.8	22.1	23.6	22.1	22.6	22.1	22.8	22.1	26.1	22.1	23.8	22.1	24.4	22.1	25.7	22.1	23.6	22.1	(Cloudy, 29/21)
12:30:00	31.9	31.0	36.5	31.0	37.9	31.0	38.6	31.0	42.3	31.0	40.2	31.0	43.3	31.0	44.6	31.0	43.9	31.0	44.4	31.0	
17:30:00	23.8	26.7	26.5	26.7	28.8	26.7	25.6	26.7	25.4	26.7	31.1	26.7	32.5	26.7	30.0	26.7	29.6	26.7	26.7	26.7	
22:30:00	21.6	23.8	23.0	23.8	24.5	23.8	25.1	23.8	24.6	23.8	26.0	23.8	26.8	23.8	21.8	23.8	21.6	23.8	22.6	23.8	
Tuesday, 22 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00	28.1	24.9	27.9	24.9	29.9	24.9	32.0	24.9	33.5	24.9	28.3	24.9	28.4	24.9	29.3	24.9	30.8	24.9	27.3	24.9	(Sunny, 33/22)
12:30:00	33.7	35.8	45.6	35.8	44.7	35.8	49.1	35.8	48.5	35.8	53.2	35.8	46.9	35.8	45.6	35.8	42.5	35.8	49.5	35.8	
17:30:00	27.3	28.1	29.8	28.1	32.1	28.1	39.2	28.1	44.8	28.1	41.0	28.1	38.3	28.1	40.5	28.1	40.9	28.1	44.5	28.1	
22:30:00	23.9	27.2	25.6	27.2	26.3	27.2	29.1	27.2	26.8	27.2	28.3	27.2	28.9	27.2	26.8	27.2	26.1	27.2	27.0	27.2	
Wednesday, 23 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00	29.6	28.2	35.4	28.2	34.8	28.2	27.1	28.2	39.6	28.2	32.7	28.2	33.3	28.2	33.8	28.2	39.6	28.2	29.4	28.2	(Sunny/Cloudy, 32/22)
12:30:00	34.8	35.0	39.9	35.0	43.4	35.0	45.8	35.0	48.2	35.0	47.9	35.0	48.0	35.0	45.3	35.0	44.2	35.0	46.9	35.0	
17:30:00	24.0	24.0	29.0	24.0	31.6	24.0	26.5	24.0	26.3	24.0	33.6	24.0	32.6	24.0	32.4	24.0	30.0	24.0	23.1	24.0	
22:30:00	22.5	22.9	24.7	22.9	26.0	22.9	26.1	22.9	28.3	22.9	29.5	22.9	29.6	22.9	28.0	22.9	27.2	22.9	23.0	22.9	
Thursday, 24 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00																					
12:30:00																					
17:30:00																					
22:30:00																					
Friday, 25 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00																					
12:30:00																					
17:30:00																					
22:30:00																					
Saturday, 26 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00																					
12:30:00																					
17:30:00																					
22:30:00																					
Sunday, 27 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00																					
12:30:00																					
17:30:00																					
22:30:00																					
Monday, 28 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00																					
12:30:00																					
17:30:00																					
22:30:00																					
Tuesday, 29 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00	31.8	26.6	30.7	26.6	32.3	26.6	28.1	26.6	31.1	26.6	30.7	26.6	29.9	26.6	31.3	26.6	31.5	26.6	25.5	26.6	(Sunny, 33/22)
12:30:00	32.6	33.9	44.7	33.9	46.2	33.9	48.4	33.9	47.0	33.9	49.3	33.9	50.8	33.9	50.2	33.9	46.8	33.9	47.2	33.9	
17:30:00	25.6	28.8	27.8	28.8	31.7	28.8	27.9	28.8	40.5	28.8	40.5	28.8	44.0	28.8	42.8	28.8	41.0	28.8	45.5	28.8	
22:30:00	22.6	28.2	27.0	28.2	26.2	28.2	28.3	28.2	25.9	28.2	27.8	28.2	29.1	28.2	28.6	28.2	25.9	28.2	25.2	28.2	
Wednesday, 30 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00	27.0	25.4	30.9	25.4	30.3	25.4	36.3	25.4	37.0	25.4	30.2	25.4	32.9	25.4	32.2	25.4	33.2	25.4	28.1	25.4	(Sunny/Cloudy, 34/23)
12:30:00	29.9	32.6	43.6	32.6	44.0	32.6	44.5	32.6	46.2	32.6	47.2	32.6	43.1	32.6	44.8	32.6	42.6	32.6	47.1	32.6	
17:30:00	24.9	29.1	27.9	29.1	30.7	29.1	24.4	29.1	29.7	29.1	34.7	29.1	31.8	29.1	31.3	29.1	31.1	29.1	27.9	29.1	
22:30:00	23.0	26.3	25.6	26.3	26.0	26.3	24.5	26.3	26.9	26.3	27.0	26.3	25.1	26.3	26.4	26.3	29.2	26.3	28.3	26.3	
Thursday, 31 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:30:00	25.9	26.2	24.7	26.2	26.7	26.2	26.1	26.2	29.9	26.2	27.8	26.2	27.5	26.2	27.9	26.2	28.4	26.2	27.3	26.2	(Sunny, 37/21)

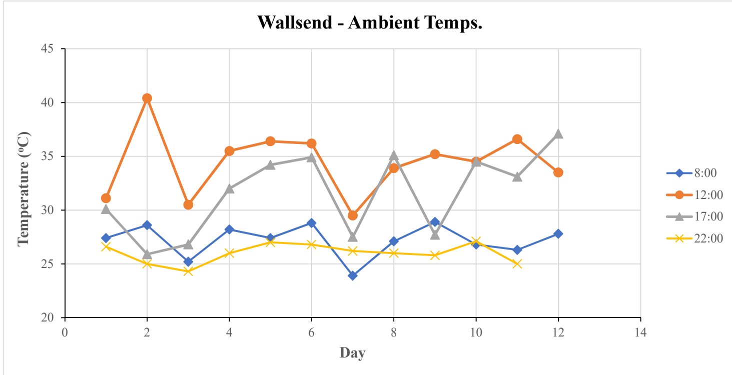
(Sunny, 37/21)

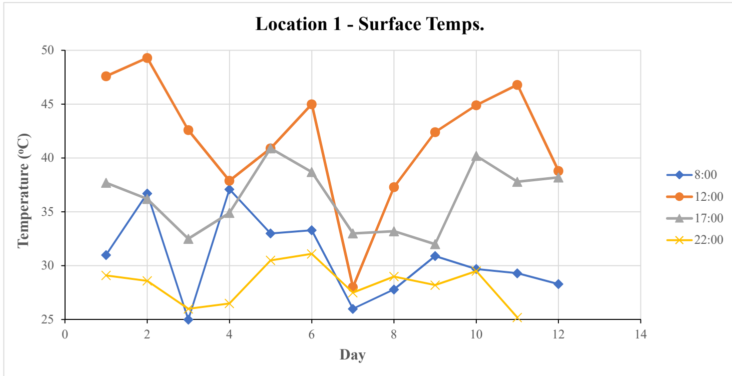
12:30:00	37.9	43.5	48.3	43.5	50.6	43.5	50.4	43.5	54.8	43.5	58.6	43.5	53.0	43.5	55.2	43.5	54.6	43.5	58.4	43.5
17:30:00	36.6	37.4	37.1	37.4	37.6	37.4	35.3	37.4	40.7	37.4	38.6	37.4	38.5	37.4	39.6	37.4	39.5	37.4	40.2	37.4
22:30:00	24.3	31.6	30.5	31.6	31.2	31.6	29.5	31.6	29.6	31.6	28.7	31.6	28.2	31.6	29.3	31.6	31.4	31.6	30.8	31.6
Friday, 1 February 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		**Data Logger no. 9**		**Data Logger no. 10**	
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**
08:00:00																				
12:00:00																				
17:00:00																				
22:00:00																				
Saturday, 2 February 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		**Data Logger no. 9**		**Data Logger no. 10**	
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**
08:00:00																				
12:00:00																				
17:00:00																				
22:00:00																				
Sunday, 3 February 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		**Data Logger no. 9**		**Data Logger no. 10**	
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**
08:00:00																				
12:00:00																				
17:00:00																				
22:00:00																				
Monday, 4 February 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		**Data Logger no. 9**		**Data Logger no. 10**	
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**
08:00:00																				
12:00:00																				
17:00:00																				
22:00:00																				
Tuesday, 5 February 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		**Data Logger no. 9**		**Data Logger no. 10**	
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**
08:00:00																				
12:00:00																				
17:00:00																				
22:00:00																				
Wednesday, 6 February 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		**Data Logger no. 9**		**Data Logger no. 10**	
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**
08:00:00																				
12:00:00																				
17:00:00																				
22:00:00																				
Thursday, 7 February 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		**Data Logger no. 9**		**Data Logger no. 10**	
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**
08:00:00																				
12:00:00																				
17:00:00																				
22:00:00																				
Friday, 8 February 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		**Data Logger no. 9**		**Data Logger no. 10**	
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**
08:00:00																				
12:00:00																				
17:00:00																				
22:00:00																				

Site 4 – Wallsend Library

SCROLL FOR ALL SITES →

LOCATION 1 (Concrete)





Ambient	
Time	Average Temp. (°C)
8:00:00	27.2
12:00:00	34.4
17:00:00	31.6
22:00:00	26.0

Surface	
Time	Average Temp. (°C)
8:00:00	30.7
12:00:00	41.8
17:00:00	36.3
22:00:00	28.3

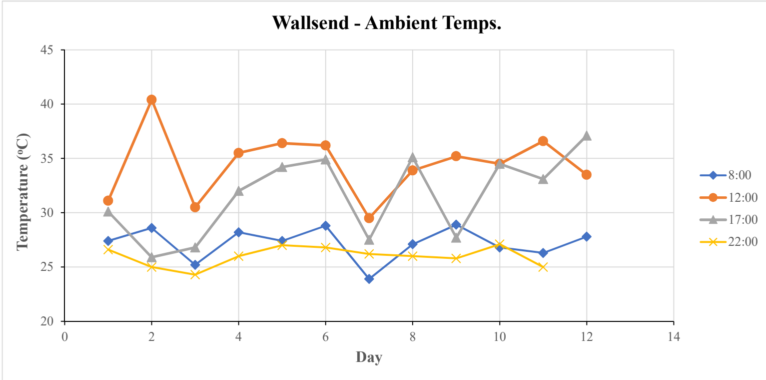
Ambient (All of Wallsend Sites)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-08	1	28, 21	27.4	31.1	30.1	26.6
Jan-09	2	30, 22	28.6	40.4	25.9	25.0
Jan-10	3	27, 21	25.2	30.5	26.8	24.3
Jan-14	4	29, 20	28.2	35.5	32.0	26.0
Jan-15	5	34, 21	27.4	36.4	34.2	27.0
Jan-16	6	35, 22	28.8	36.2	34.9	26.8
Jan-21	7	29, 21	23.9	29.5	27.5	26.2
Jan-22	8	33, 22	27.1	33.9	35.1	26.0
Jan-23	9	32, 22	28.9	35.2	27.7	25.8
Jan-29	10	33, 22	26.8	34.5	34.5	27.1
Jan-30	11	34, 23	26.3	36.6	33.1	25.0
Jan-31	12	37, 21	27.8	33.5	37.1	
Data Collection Concluded						
Average Temp. (°C)			27.2	34.4	31.6	26.0

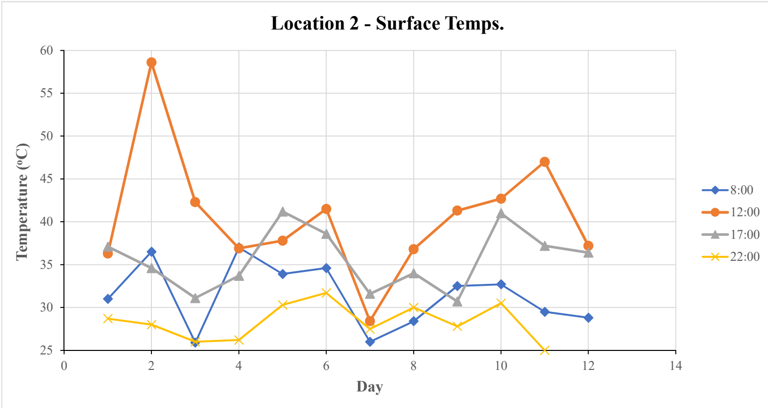
Surface (Location 1)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-08	1	28, 21	31.0	47.6	37.7	29.1
Jan-09	2	30, 22	36.7	49.3	36.2	28.6
Jan-10	3	27, 21	25.0	42.6	32.5	26.0
Jan-14	4	29, 20	37.1	37.9	34.9	26.5
Jan-15	5	34, 21	33.0	40.9	40.9	30.5
Jan-16	6	35, 22	33.3	45.0	38.7	31.1
Jan-21	7	29, 21	26.0	28.0	33.0	27.5
Jan-22	8	33, 22	27.8	37.3	33.2	29.0
Jan-23	9	32, 22	30.9	42.4	32.0	28.2
Jan-29	10	33, 22	29.7	44.9	40.2	29.5
Jan-30	11	34, 23	29.3	46.8	37.8	25.2
Jan-31	12	37, 21	28.3	38.8	38.2	
Data Collection Concluded						
Average Temp. (°C)			30.7	41.8	36.3	28.3

LOCATION 2 (Pebblecrete)



Ambient	
Time	Average Temp. (°C)
8:00:00	27.2
12:00:00	34.4
17:00:00	31.6
22:00:00	26.0

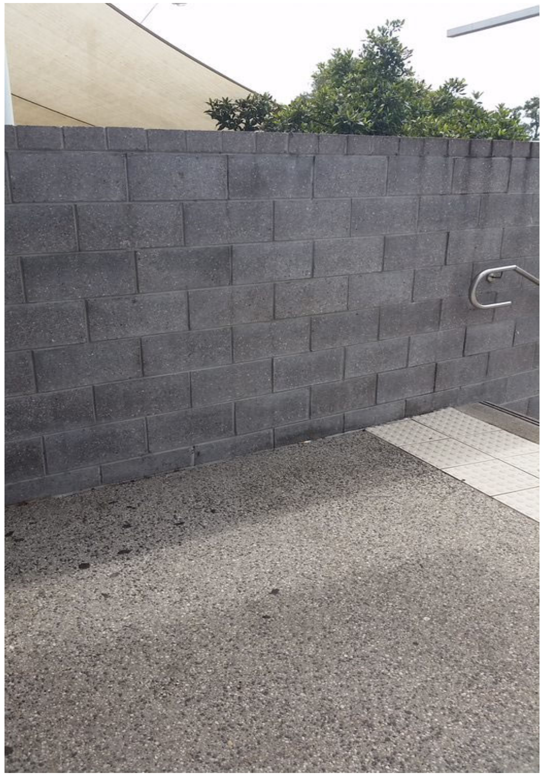


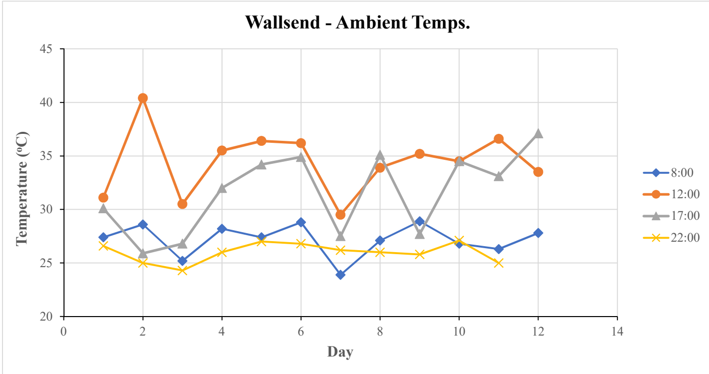
Surface	
Time	Average Temp. (°C)
8:00:00	31.4
12:00:00	40.6
17:00:00	35.6
22:00:00	28.3

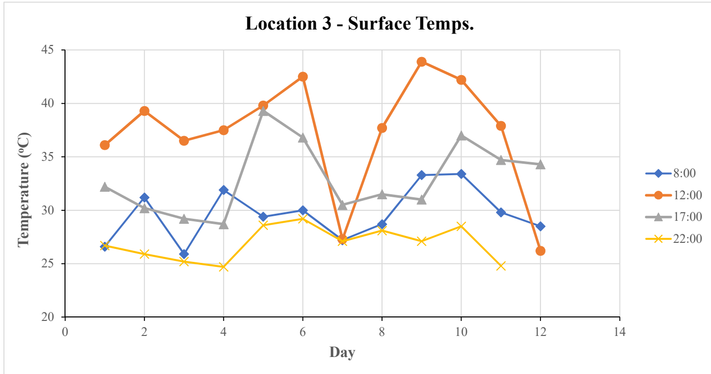
Ambient (All of Wallsend Sites)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-08	1	28, 21	27.4	31.1	30.1	26.6
Jan-09	2	30, 22	28.6	40.4	25.9	25.0
Jan-10	3	27, 21	25.2	30.5	26.8	24.3
Jan-14	4	29, 20	28.2	35.5	32.0	26.0
Jan-15	5	34, 21	27.4	36.4	34.2	27.0
Jan-16	6	35, 22	28.8	36.2	34.9	26.8
Jan-21	7	29, 21	23.9	29.5	27.5	26.2
Jan-22	8	33, 22	27.1	33.9	35.1	26.0
Jan-23	9	32, 22	28.9	35.2	27.7	25.8
Jan-29	10	33, 22	26.8	34.5	34.5	27.1
Jan-30	11	34, 23	26.3	36.6	33.1	25.0
Jan-31	12	37, 21	27.8	33.5	37.1	
Data Collection Concluded						
Average Temp. (°C)			27.2	34.4	31.6	26.0

Surface (Location 2)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-08	1	28, 21	31.0	36.3	37.1	28.7
Jan-09	2	30, 22	36.5	58.6	34.6	28.0
Jan-10	3	27, 21	25.9	42.3	31.1	26.0
Jan-14	4	29, 20	37.0	36.9	33.7	26.2
Jan-15	5	34, 21	33.9	37.8	41.2	30.3
Jan-16	6	35, 22	34.6	41.5	38.6	31.7
Jan-21	7	29, 21	26.0	28.4	31.6	27.5
Jan-22	8	33, 22	28.4	36.8	34.0	30.0
Jan-23	9	32, 22	32.5	41.3	30.7	27.8
Jan-29	10	33, 22	32.7	42.7	41.0	30.5
Jan-30	11	34, 23	29.5	47.0	37.2	25.0
Jan-31	12	37, 21	28.8	37.2	36.4	
Data Collection Concluded						
Average Temp. (°C)			31.4	40.6	35.6	28.3

LOCATION 3 (Pebblecrete)







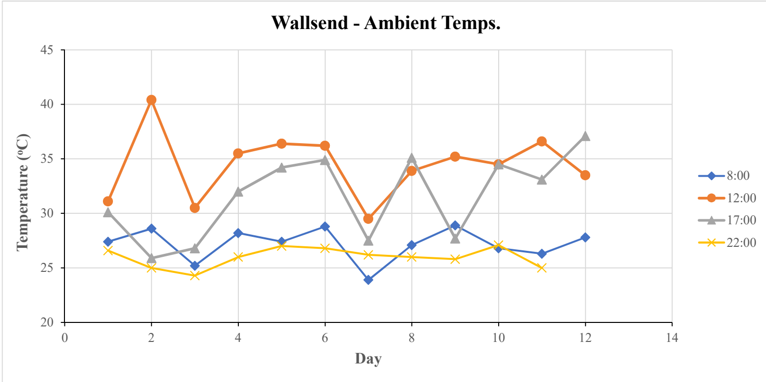
Ambient	
Time	Average Temp. (°C)
8:00:00	27.2
12:00:00	34.4
17:00:00	31.6
22:00:00	26.0

Surface	
Time	Average Temp. (°C)
8:00:00	29.7
12:00:00	37.2
17:00:00	33.0
22:00:00	26.9

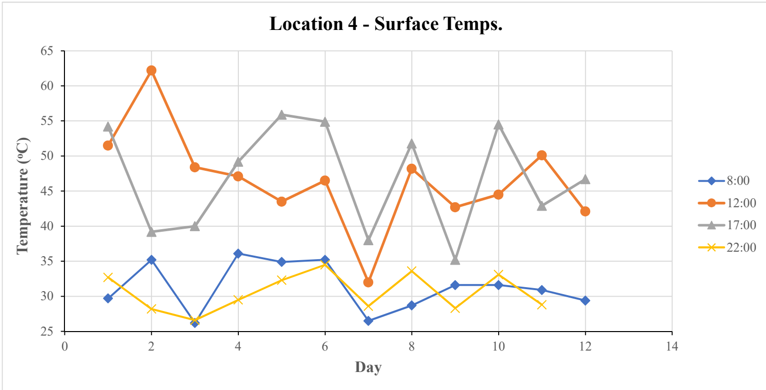
Ambient (All of Wallsend Sites)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-08	1	28, 21	27.4	31.1	30.1	26.6
Jan-09	2	30, 22	28.6	40.4	25.9	25.0
Jan-10	3	27, 21	25.2	30.5	26.8	24.3
Jan-14	4	29, 20	28.2	35.5	32.0	26.0
Jan-15	5	34, 21	27.4	36.4	34.2	27.0
Jan-16	6	35, 22	28.8	36.2	34.9	26.8
Jan-21	7	29, 21	23.9	29.5	27.5	26.2
Jan-22	8	33, 22	27.1	33.9	35.1	26.0
Jan-23	9	32, 22	28.9	35.2	27.7	25.8
Jan-29	10	33, 22	26.8	34.5	34.5	27.1
Jan-30	11	34, 23	26.3	36.6	33.1	25.0
Jan-31	12	37, 21	27.8	33.5	37.1	
Data Collection Concluded						
Average Temp. (°C)			27.2	34.4	31.6	26.0

Surface (Location 3)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-08	1	28, 21	26.6	36.1	32.2	26.7
Jan-09	2	30, 22	31.2	39.3	30.2	25.9
Jan-10	3	27, 21	25.9	36.5	29.2	25.2
Jan-14	4	29, 20	31.9	37.5	28.7	24.7
Jan-15	5	34, 21	29.4	39.8	39.3	28.6
Jan-16	6	35, 22	30.0	42.5	36.8	29.2
Jan-21	7	29, 21	27.2	27.3	30.5	27.1
Jan-22	8	33, 22	28.7	37.7	31.5	28.1
Jan-23	9	32, 22	33.3	43.9	31.0	27.1
Jan-29	10	33, 22	33.4	42.2	37.0	28.5
Jan-30	11	34, 23	29.8	37.9	34.7	24.8
Jan-31	12	37, 21	28.5	26.2	34.3	
Data Collection Concluded						
Average Temp. (°C)			29.7	37.2	33.0	26.9

LOCATION 4 (Concrete)



Ambient	
Time	Average Temp. (°C)
8:00:00	27.2
12:00:00	34.4
17:00:00	31.6
22:00:00	26.0

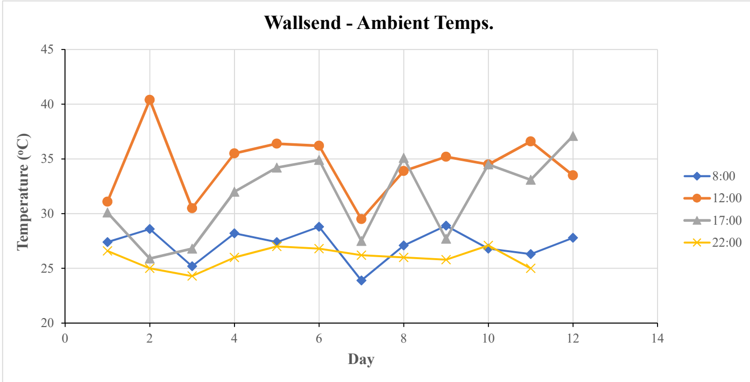


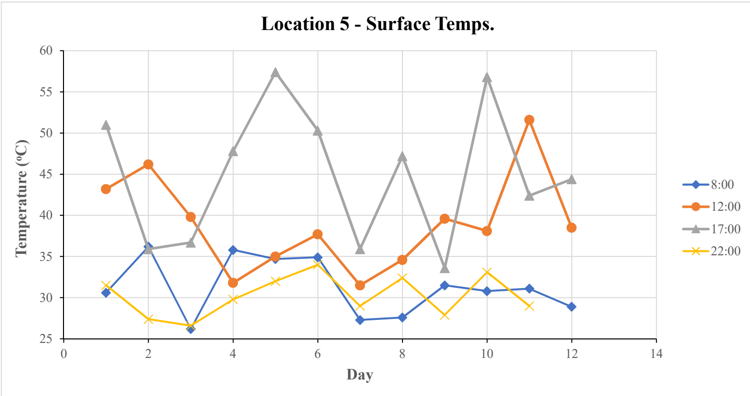
Surface	
Time	Average Temp. (°C)
8:00:00	31.3
12:00:00	46.6
17:00:00	46.9
22:00:00	30.6

Ambient (All of Wallsend Sites)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-08	1	28, 21	27.4	31.1	30.1	26.6
Jan-09	2	30, 22	28.6	40.4	25.9	25.0
Jan-10	3	27, 21	25.2	30.5	26.8	24.3
Jan-14	4	29, 20	28.2	35.5	32.0	26.0
Jan-15	5	34, 21	27.4	36.4	34.2	27.0
Jan-16	6	35, 22	28.8	36.2	34.9	26.8
Jan-21	7	29, 21	23.9	29.5	27.5	26.2
Jan-22	8	33, 22	27.1	33.9	35.1	26.0
Jan-23	9	32, 22	28.9	35.2	27.7	25.8
Jan-29	10	33, 22	26.8	34.5	34.5	27.1
Jan-30	11	34, 23	26.3	36.6	33.1	25.0
Jan-31	12	37, 21	27.8	33.5	37.1	
Data Collection Concluded						
Average Temp. (°C)			27.2	34.4	31.6	26.0

Surface (Location 4)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (oC)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-08	1	28, 21	29.7	51.5	54.2	32.7
Jan-09	2	30, 22	35.2	62.2	39.2	28.2
Jan-10	3	27, 21	26.2	48.4	40.0	26.6
Jan-14	4	29, 20	36.1	47.1	49.2	29.5
Jan-15	5	34, 21	34.9	43.5	55.9	32.3
Jan-16	6	35, 22	35.2	46.5	54.9	34.5
Jan-21	7	29, 21	26.5	32.0	38.0	28.6
Jan-22	8	33, 22	28.7	48.2	51.8	33.6
Jan-23	9	32, 22	31.6	42.7	35.2	28.3
Jan-29	10	33, 22	31.6	44.5	54.5	33.1
Jan-30	11	34, 23	30.9	50.1	42.9	28.8
Jan-31	12	37, 21	29.4	42.1	46.7	
Data Collection Concluded						
Average Temp. (°C)			31.3	46.6	46.9	30.6

LOCATION 5 (Concrete)





Ambient	
Time	Average Temp. (°C)
8:00:00	27.2
12:00:00	34.4
17:00:00	31.6
22:00:00	26.0

Surface	
Time	Average Temp. (°C)
8:00:00	31.3
12:00:00	39.0
17:00:00	45.0
22:00:00	30.2

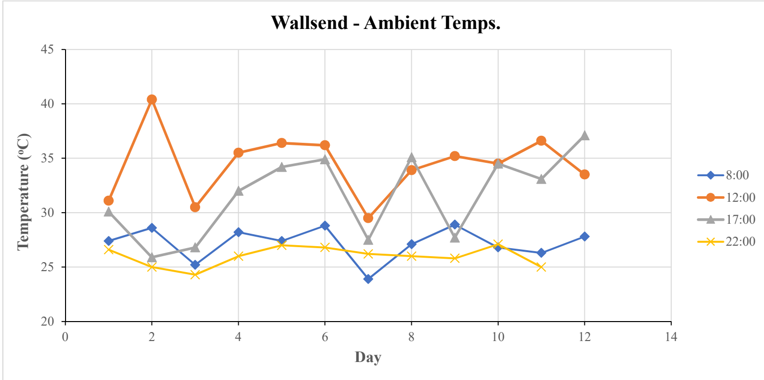
Ambient (All of Wallsend Sites)

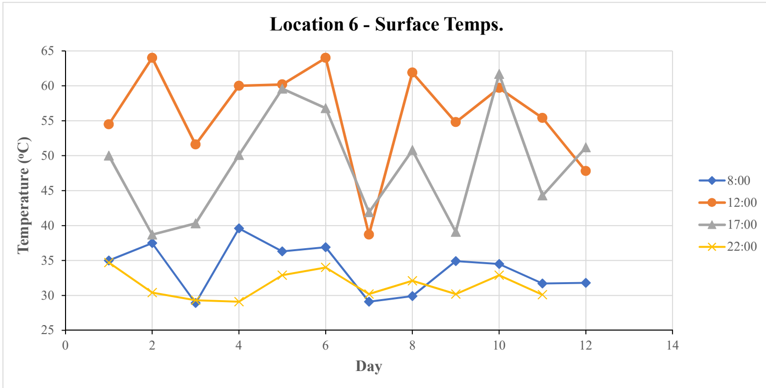
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-08	1	28, 21	27.4	31.1	30.1	26.6
Jan-09	2	30, 22	28.6	40.4	25.9	25.0
Jan-10	3	27, 21	25.2	30.5	26.8	24.3
Jan-14	4	29, 20	28.2	35.5	32.0	26.0
Jan-15	5	34, 21	27.4	36.4	34.2	27.0
Jan-16	6	35, 22	28.8	36.2	34.9	26.8
Jan-21	7	29, 21	23.9	29.5	27.5	26.2
Jan-22	8	33, 22	27.1	33.9	35.1	26.0
Jan-23	9	32, 22	28.9	35.2	27.7	25.8
Jan-29	10	33, 22	26.8	34.5	34.5	27.1
Jan-30	11	34, 23	26.3	36.6	33.1	25.0
Jan-31	12	37, 21	27.8	33.5	37.1	
Data Collection Concluded						
Average Temp. (°C)			27.2	34.4	31.6	26.0

Surface (Location 5)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-08	1	28, 21	30.6	43.2	51.0	31.5
Jan-09	2	30, 22	36.2	46.2	35.9	27.4
Jan-10	3	27, 21	26.2	39.8	36.7	26.6
Jan-14	4	29, 20	35.8	31.8	47.8	29.8
Jan-15	5	34, 21	34.7	35.0	57.4	32.0
Jan-16	6	35, 22	34.9	37.7	50.3	34.0
Jan-21	7	29, 21	27.3	31.5	35.9	29.0
Jan-22	8	33, 22	27.6	34.6	47.2	32.4
Jan-23	9	32, 22	31.5	39.6	33.6	27.9
Jan-29	10	33, 22	30.8	38.1	56.8	33.1
Jan-30	11	34, 23	31.1	51.6	42.4	29.0
Jan-31	12	37, 21	28.9	38.5	44.4	
Data Collection Concluded						
Average Temp. (°C)			31.3	39.0	45.0	30.2

LOCATION 6 (Bitumen)





Ambient	
Time	Average Temp. (°C)
8:00:00	27.2
12:00:00	34.4
17:00:00	31.6
22:00:00	26.0

Surface	
Time	Average Temp. (°C)
8:00:00	33.8
12:00:00	56.1
17:00:00	48.7
22:00:00	31.4

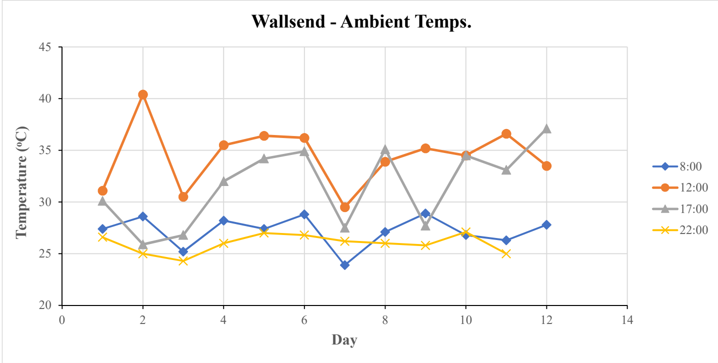
Ambient (All of Wallsend Sites)

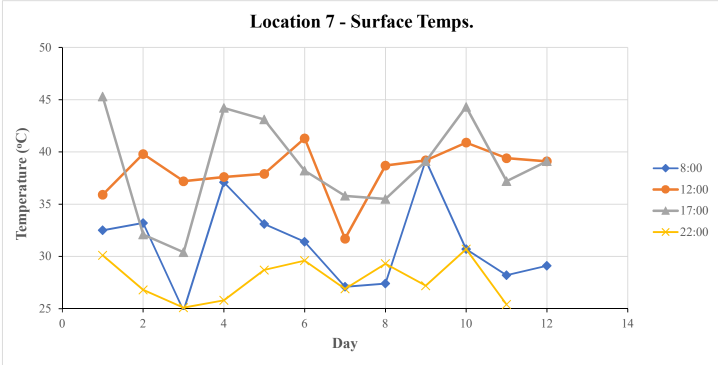
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-08	1	28, 21	27.4	31.1	30.1	26.6
Jan-09	2	30, 22	28.6	40.4	25.9	25.0
Jan-10	3	27, 21	25.2	30.5	26.8	24.3
Jan-14	4	29, 20	28.2	35.5	32.0	26.0
Jan-15	5	34, 21	27.4	36.4	34.2	27.0
Jan-16	6	35, 22	28.8	36.2	34.9	26.8
Jan-21	7	29, 21	23.9	29.5	27.5	26.2
Jan-22	8	33, 22	27.1	33.9	35.1	26.0
Jan-23	9	32, 22	28.9	35.2	27.7	25.8
Jan-29	10	33, 22	26.8	34.5	34.5	27.1
Jan-30	11	34, 23	26.3	36.6	33.1	25.0
Jan-31	12	37, 21	27.8	33.5	37.1	
Data Collection Concluded						
Average Temp. (°C)			27.2	34.4	31.6	26.0

Surface (Location 6)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-08	1	28, 21	35.0	54.5	50.0	34.7
Jan-09	2	30, 22	37.5	64.0	38.7	30.4
Jan-10	3	27, 21	28.9	51.6	40.3	29.3
Jan-14	4	29, 20	39.6	60.0	50.1	29.1
Jan-15	5	34, 21	36.3	60.2	59.6	32.9
Jan-16	6	35, 22	36.9	64.0	56.8	34.0
Jan-21	7	29, 21	29.1	38.7	41.9	30.2
Jan-22	8	33, 22	29.9	61.9	50.8	32.1
Jan-23	9	32, 22	34.9	54.8	39.1	30.2
Jan-29	10	33, 22	34.5	59.7	61.7	32.9
Jan-30	11	34, 23	31.7	55.4	44.3	30.1
Jan-31	12	37, 21	31.8	47.8	51.2	
Data Collection Concluded						
Average Temp. (°C)			33.8	56.1	48.7	31.4

LOCATION 7 (Bitumen)





Ambient	
Time	Average Temp. (°C)
8:00:00	27.2
12:00:00	34.4
17:00:00	31.6
22:00:00	26.0

Surface	
Time	Average Temp. (°C)
8:00:00	31.2
12:00:00	38.2
17:00:00	38.7
22:00:00	27.8

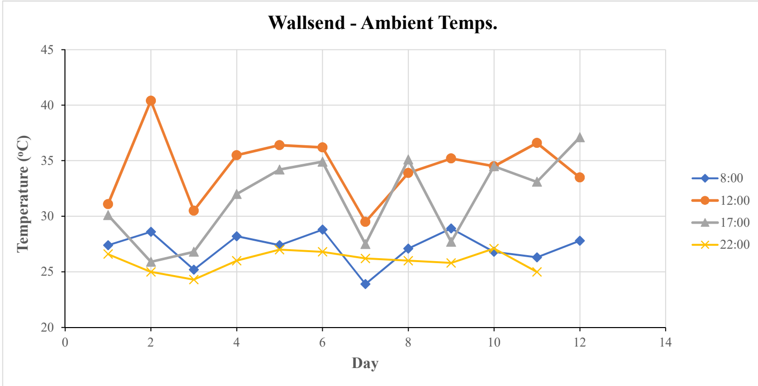
Ambient (All of Wallsend Sites)

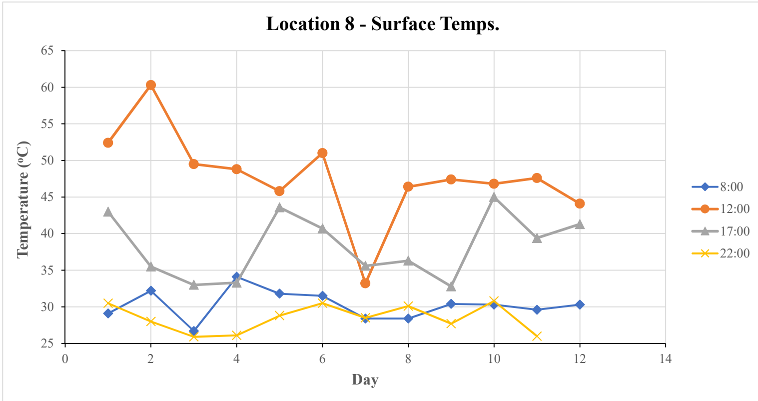
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-08	1	28, 21	27.4	31.1	30.1	26.6
Jan-09	2	30, 22	28.6	40.4	25.9	25.0
Jan-10	3	27, 21	25.2	30.5	26.8	24.3
Jan-14	4	29, 20	28.2	35.5	32.0	26.0
Jan-15	5	34, 21	27.4	36.4	34.2	27.0
Jan-16	6	35, 22	28.8	36.2	34.9	26.8
Jan-21	7	29, 21	23.9	29.5	27.5	26.2
Jan-22	8	33, 22	27.1	33.9	35.1	26.0
Jan-23	9	32, 22	28.9	35.2	27.7	25.8
Jan-29	10	33, 22	26.8	34.5	34.5	27.1
Jan-30	11	34, 23	26.3	36.6	33.1	25.0
Jan-31	12	37, 21	27.8	33.5	37.1	
Data Collection Concluded						
Average Temp. (°C)			27.2	34.4	31.6	26.0

Surface (Location 7)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-08	1	28, 21	32.5	35.9	45.3	30.1
Jan-09	2	30, 22	33.2	39.8	32.1	26.8
Jan-10	3	27, 21	24.8	37.2	30.4	25.1
Jan-14	4	29, 20	37.1	37.6	44.2	25.8
Jan-15	5	34, 21	33.1	37.9	43.1	28.7
Jan-16	6	35, 22	31.4	41.3	38.2	29.6
Jan-21	7	29, 21	27.1	31.7	35.8	26.9
Jan-22	8	33, 22	27.4	38.7	35.5	29.3
Jan-23	9	32, 22	39.2	39.2	39.1	27.2
Jan-29	10	33, 22	30.7	40.9	44.3	30.7
Jan-30	11	34, 23	28.2	39.4	37.2	25.4
Jan-31	12	37, 21	29.1	39.1	39.1	
Data Collection Concluded						
Average Temp. (°C)			31.2	38.2	38.7	27.8

LOCATION 8 (Paver)





Ambient	
Time	Average Temp. (°C)
8:00:00	27.2
12:00:00	34.4
17:00:00	31.6
22:00:00	26.0

Surface	
Time	Average Temp. (°C)
8:00:00	30.2
12:00:00	47.8
17:00:00	38.3
22:00:00	28.4

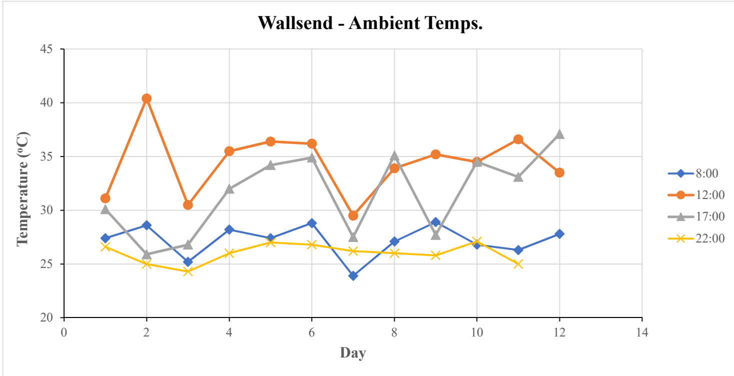
Ambient (All of Wallsend Sites)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-08	1	28, 21	27.4	31.1	30.1	26.6
Jan-09	2	30, 22	28.6	40.4	25.9	25.0
Jan-10	3	27, 21	25.2	30.5	26.8	24.3
Jan-14	4	29, 20	28.2	35.5	32.0	26.0
Jan-15	5	34, 21	27.4	36.4	34.2	27.0
Jan-16	6	35, 22	28.8	36.2	34.9	26.8
Jan-21	7	29, 21	23.9	29.5	27.5	26.2
Jan-22	8	33, 22	27.1	33.9	35.1	26.0
Jan-23	9	32, 22	28.9	35.2	27.7	25.8
Jan-29	10	33, 22	26.8	34.5	34.5	27.1
Jan-30	11	34, 23	26.3	36.6	33.1	25.0
Jan-31	12	37, 21	27.8	33.5	37.1	
Data Collection Concluded						
Average Temp. (°C)			27.2	34.4	31.6	26.0

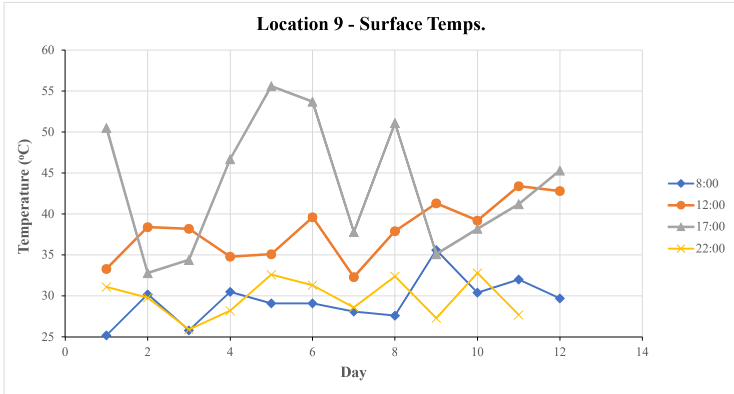
Surface (Location 8)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-08	1	28, 21	29.1	52.4	43.0	30.5
Jan-09	2	30, 22	32.2	60.3	35.5	28.0
Jan-10	3	27, 21	26.7	49.5	33.0	25.9
Jan-14	4	29, 20	34.1	48.8	33.3	26.1
Jan-15	5	34, 21	31.8	45.8	43.6	28.8
Jan-16	6	35, 22	31.5	51.0	40.7	30.5
Jan-21	7	29, 21	28.4	33.2	35.6	28.5
Jan-22	8	33, 22	28.4	46.4	36.3	30.1
Jan-23	9	32, 22	30.4	47.4	32.8	27.7
Jan-29	10	33, 22	30.3	46.8	45.0	30.8
Jan-30	11	34, 23	29.6	47.6	39.4	26.0
Jan-31	12	37, 21	30.3	44.1	41.3	
Data Collection Concluded						
Average Temp. (°C)			30.2	47.8	38.3	28.4

LOCATION 9 (Paver)



Ambient	
Time	Average Temp. (°C)
8:00:00	27.2
12:00:00	34.4
17:00:00	31.6
22:00:00	26.0



Surface	
Time	Average Temp. (°C)
8:00:00	29.4
12:00:00	38.0
17:00:00	43.5
22:00:00	29.8

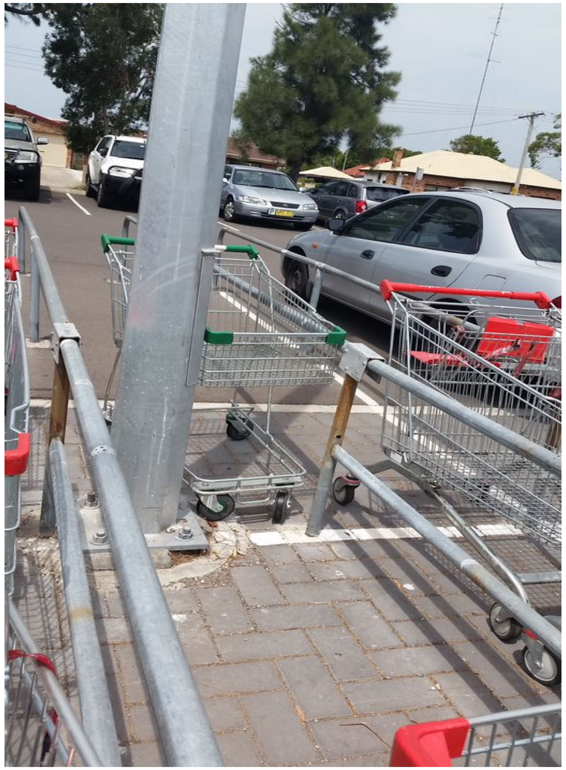
Ambient (All of Wallsend Sites)

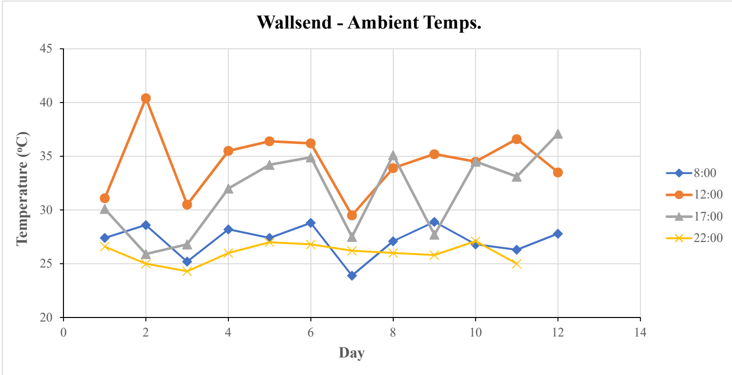
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-08	1	28, 21	27.4	31.1	30.1	26.6
Jan-09	2	30, 22	28.6	40.4	25.9	25.0
Jan-10	3	27, 21	25.2	30.5	26.8	24.3
Jan-14	4	29, 20	28.2	35.5	32.0	26.0
Jan-15	5	34, 21	27.4	36.4	34.2	27.0
Jan-16	6	35, 22	28.8	36.2	34.9	26.8
Jan-21	7	29, 21	23.9	29.5	27.5	26.2
Jan-22	8	33, 22	27.1	33.9	35.1	26.0
Jan-23	9	32, 22	28.9	35.2	27.7	25.8
Jan-29	10	33, 22	26.8	34.5	34.5	27.1
Jan-30	11	34, 23	26.3	36.6	33.1	25.0
Jan-31	12	37, 21	27.8	33.5	37.1	
Data Collection Concluded						
Average Temp. (°C)			27.2	34.4	31.6	26.0

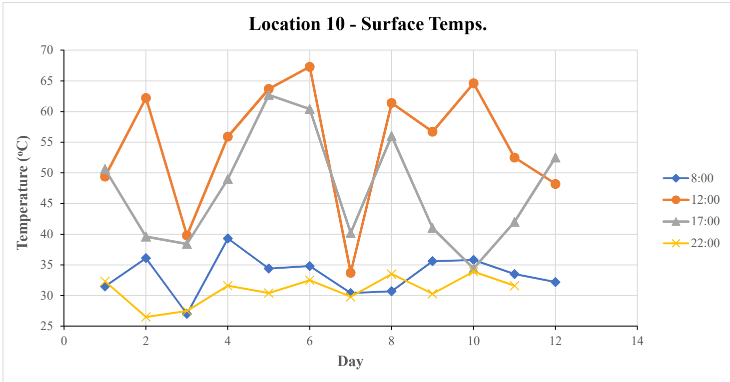
Surface (Location 9)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-08	1	28, 21	25.2	33.3	50.5	31.1
Jan-09	2	30, 22	30.2	38.4	32.8	29.8
Jan-10	3	27, 21	25.8	38.2	34.4	25.9
Jan-14	4	29, 20	30.5	34.8	46.7	28.2
Jan-15	5	34, 21	29.1	35.1	55.6	32.6
Jan-16	6	35, 22	29.1	39.6	53.7	31.3
Jan-21	7	29, 21	28.1	32.3	37.8	28.6
Jan-22	8	33, 22	27.6	37.9	51.1	32.4
Jan-23	9	32, 22	35.6	41.3	35.1	27.3
Jan-29	10	33, 22	30.4	39.2	38.2	32.8
Jan-30	11	34, 23	32.0	43.4	41.2	27.7
Jan-31	12	37, 21	29.7	42.8	45.3	
Data Collection Concluded						
Average Temp. (°C)			29.4	38.0	43.5	29.8

LOCATION 10 (Permeable paver)







Ambient	
Time	**Average Temp. (°C)**
8:00:00	27.2
12:00:00	34.4
17:00:00	31.6
22:00:00	26.0

Surface	
Time	**Average Temp. (°C)**
8:00:00	33.4
12:00:00	54.6
17:00:00	47.2
22:00:00	30.9

Ambient (All of Wallsend Sites)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-08	1	28, 21	27.4	31.1	30.1	26.6
Jan-09	2	30, 22	28.6	40.4	25.9	25.0
Jan-10	3	27, 21	25.2	30.5	26.8	24.3
Jan-14	4	29, 20	28.2	35.5	32.0	26.0
Jan-15	5	34, 21	27.4	36.4	34.2	27.0
Jan-16	6	35, 22	28.8	36.2	34.9	26.8
Jan-21	7	29, 21	23.9	29.5	27.5	26.2
Jan-22	8	33, 22	27.1	33.9	35.1	26.0
Jan-23	9	32, 22	28.9	35.2	27.7	25.8
Jan-29	10	33, 22	26.8	34.5	34.5	27.1
Jan-30	11	34, 23	26.3	36.6	33.1	25.0
Jan-31	12	37, 21	27.8	33.5	37.1	
Data Collection Concluded						
Average Temp. (°C)			27.2	34.4	31.6	26.0

Surface (Location 10)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			8:00:00	12:00:00	17:00:00	22:00:00
Jan-08	1	28, 21	31.5	49.4	50.6	32.3
Jan-09	2	30, 22	36.1	62.2	39.6	26.5
Jan-10	3	27, 21	27.0	39.8	38.4	27.5
Jan-14	4	29, 20	39.3	55.9	49.0	31.6
Jan-15	5	34, 21	34.4	63.7	62.7	30.4
Jan-16	6	35, 22	34.8	67.3	60.4	32.5
Jan-21	7	29, 21	30.4	33.7	40.2	29.8
Jan-22	8	33, 22	30.7	61.4	56.0	33.5
Jan-23	9	32, 22	35.6	56.7	41.0	30.3
Jan-29	10	33, 22	35.8	64.6	34.4	33.9
Jan-30	11	34, 23	33.5	52.5	42.0	31.6
Jan-31	12	37, 21	32.2	48.2	52.5	
Data Collection Concluded						
Average Temp. (°C)			33.4	54.6	47.2	30.9

Site 4 – Wallsend Library

Date	Temperature Readings (°C)																				
Monday, 7 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		Air
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					
17:00:00																					
22:00:00																					
Tuesday, 8 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		Air
Time	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	
08:00:00	31.0	Conc. F.S	31.0	PBLcrete. F.S	26.6	PBLcrete. F.S	29.7	conc. F.S.	30.6	conc. F.S.	35	bitumin. F.S	32.5	bitumin. F.S.	29.1	paver. F.S	25.2	paver. Sh.	31.5	P.paver. F.S	27.4
12:00:00	47.6	Conc. Part.Sh.	36.3	PBLcrete. PtSh	36.1	PBLcrete. Sh.	51.5	conc. F.S.	43.2	conc. PtSh.	54.5	bitumin. F.S	35.9	bitumin. PtSh	52.4	paver. F.S	33.3	paver. Sh.	49.4	P.paver. F.S	31.1
17:00:00	37.7	Conc. Sh	37.1	PBLcrete. Sh	32.2	PBLcrete. Sh.	54.2	conc. F.S.	51	conc. F.S.	50	bitumin. Pt.S	45.3	bitumin. F.S.	43	paver. F.S	50.5	paver. FS.	50.6	P.paver. F.S	30.1
22:00:00	29.1	Conc. Dark.	28.7	PBLcrete. Drk	26.7	PBLcrete. Drk	32.7	Conc. Drk	31.5	Conc. Dark	34.7	bitumin. Drk	30.1	bitumin. Drk	30.5	Paver. Drk	31.1	Paver. Drk	32.3	P.paver Drk	26.6
Wednesday, 9 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		Air
Time	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	
08:00:00	36.7	Conc. F.S	36.5	PBLcrete. F.S	31.2	PBLcrete. F.S	35.2	conc. F.S.	36.2	conc. F.S.	37.5	bitumin. F.S	33.2	bitumin. F.S.	32.2	paver. F.S	30.2	paver. Sh.	36.1	P.paver. F.S	28.6
12:00:00	49.3	Conc. Part.Sh.	58.6	PBLcrete. PtSh	39.3	PBLcrete. Sh.	62.2	conc. F.S.	46.2	conc. PtSh.	64	bitumin. F.S	39.8	bitumin. PtSh	60.3	paver. F.S	38.4	paver. Sh.	62.2	P.paver. F.S	40.4
17:00:00	36.2	conc. Sh	34.6	PBLcrete. Sh	30.2	PBLcrete. Sh.	39.2	conc. F.S.	35.9	conc. F.S.	38.7	bitumin. Pt.S	32.1	bitumin. F.S.	35.5	paver F.S	32.8	paver F.S	39.6	P.paver. F.S	25.9
22:00:00	28.6	Conc. Drk.	28	PBLcrete. Drk	25.9	PBLcrete. Drk	28.2	conc. F.S.	27.4	Conc. Dark	30.4	bitumin. Drk	26.8	bitumin. Drk	28	Paver. Drk	29.8	Paver. Drk	26.5	P.paver Drk	25
Thursday, 10 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		Air
Time	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	
08:00:00	25	conc. O.cast	25.9	PBLcrete. Ocast	25.9	PBLcrete. Ocas	26.2	Conc. Ocast	26.2	Conc. Ocast	28.9	bitumin. Ocast	24.8	bitumin. Ocast	26.7	Paver. Ocast	25.8	Paver. Ocast	27	P.paver. Ocast	25.2
12:00:00	42.6	Conc. Part.Sh.	42.3	PBLcrete. PtSh	36.5	PBLcrete. Sh.	48.4	conc. F.S.	39.8	conc. F.S.	51.6	bitumin. F.S	37.2	bitumin. PtSh	49.5	paver F.S	38.2	paver. Sh.	39.8	P.paver. F.S	30.5
17:00:00	32.5	Conc. Sh	31.1	PBLcrete. Sh	29.2	PBLcrete. Sh.	40	conc. F.S.	36.7	conc. F.S.	40.3	bitumin. Pt.S	30.4	bitumin. F.S.	33	paver F.S	34.4	paver. FS.	38.4	P.paver. F.S	26.8
22:00:00	26	Conc. Dark.	26	PBLcrete. Drk	25.2	PBLcrete. Drk	26.6	conc. F.S.	26.6	conc. F.S.	29.3	bitumin. Drk	25.1	bitumin. Drk	25.9	Paver. Drk	25.9	Paver. Drk	27.5	P.paver Drk	24.3
Friday, 11 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					
17:00:00																					
22:00:00																					
Saturday, 12 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					
17:00:00																					
22:00:00																					
Sunday, 13 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					
17:00:00																					
22:00:00																					
Monday, 14 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		Air
Time	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	
08:00:00	37.1	Conc. F.S	37	PBLcrete. F.S	31.9	PBLcrete. Sh.	36.1	conc. F.S.	35.8	conc. F.S.	39.6	bitumin. F.S	37.1	bitumin. PtSh	34.1	paver F.S	30.5	paver. Sh.	39.3	P.paver. F.S	28.2
12:00:00	37.9	Conc. Part.Sh.	36.9	PBLcrete. PtSh	37.5	PBLcrete. Sh.	47.1	conc. F.S.	31.8	conc. F.S.	60	bitumin. F.S	37.6	bitumin. F.S.	48.8	paver F.S	34.8	paver. Sh.	55.9	P.paver. F.S	35.5
17:00:00	34.9	Conc. Sh	33.7	PBLcrete. Sh	28.7	PBLcrete. Sh.	49.2	conc. F.S.	47.8	conc. F.S.	50.1	bitumin. F.S	44.2	bitumin. F.S.	33.3	paver F.S	46.7	paver F.S	49	P.paver. F.S	32
22:00:00	26.5	Conc. Drk.	26.2	PBLcrete. Drk	24.7	PBLcrete. Drk	29.5	Conc. Drk	29.8	Conc. Dark	29.1	bitumin. Drk	25.8	bitumin. Drk	26.1	Paver. Drk	28.2	Paver. Drk	31.6	P.paver Drk	26
Tuesday, 15 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		Air
Time	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	
08:00:00	33	Conc. F.S	33.9	PBLcrete. F.S	29.4	PBLcrete. Sh.	34.9	conc. F.S.	34.7	conc. F.S.	36.3	bitumin. F.S	33.1	bitumin. F.S.	31.8	paver F.S	29.1	paver. Sh.	34.4	P.paver. F.S	27.4
12:00:00	40.9	Conc. Part.Sh.	37.8	PBLcrete. PtSh	39.8	PBLcrete. Sh.	43.5	conc. F.S.	35	conc. F.S.	60.2	bitumin. F.S	37.9	bitumin. F.S.	45.8	paver F.S	35.1	paver. Sh.	63.7	P.paver. F.S	36.4
17:00:00	40.9	Conc. Sh	41.2	PBLcrete. Sh	39.3	PBLcrete. Sh.	55.9	conc. F.S.	57.4	conc. F.S.	59.6	bitumin. F.S	43.1	bitumin. F.S.	43.6	paver F.S	55.6	paver F.S	62.7	P.paver. F.S	34.2
22:00:00	30.5	Conc. Drk.	30.3	PBLcrete. Drk	28.6	PBLcrete. Drk	32.3	Conc. Drk	32	Conc. Dark	32.9	bitumin. Drk	28.7	bitumin. Drk	28.8	Paver. Drk	32.6	Paver. Drk	30.4	P.paver Drk	27
Wednesday, 16 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		Air
Time	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	
08:00:00	33.3	Conc. F.S	34.6	PBLcrete. F.S	30	PBLcrete. Sh.	35.2	conc. F.S.	34.9	conc. F.S.	36.9	bitumin. F.S	31.4	bitumin. F.S.	31.5	paver F.S	29.1	paver. Sh.	34.8	P.paver. F.S	28.8
12:00:00	45	Conc. F.S	41.5	PBLcrete. PtSh	42.5	PBLcrete. Sh.	46.5	conc. F.S.	37.7	conc. F.S.	64	bitumin. F.S	41.3	bitumin. F.S.	51	paver F.S	39.6	paver. Sh.	67.3	P.paver. F.S	36.2
17:00:00	38.7	Conc. Sh	38.6	PBLcrete. Sh	36.8	PBLcrete. Sh.	54.9	conc. F.S.	50.3	conc. F.S.	56.8	bitumin. F.S	38.2	bitumin. F.S.	40.7	paver F.S	53.7	paver F.S	60.4	P.paver. F.S	34.9
22:00:00	31.1	Conc. Drk.	31.7	PBLcrete. Drk	29.2	PBLcrete. Drk	34.5	Conc. Drk	34	Conc. Dark	34	bitumin. Drk	29.6	bitumin. Drk	30.5	Paver. Drk	31.3	Paver. Drk	32.5	P.paver Dark	26.8
Thursday, 17 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					
17:00:00																					
22:00:00																					
Friday, 18 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					

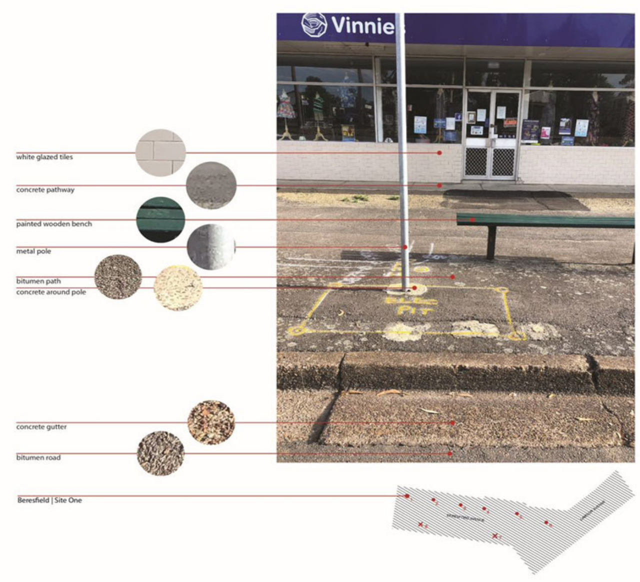
12:00:00																					
17:00:00																					
22:00:00																					
Saturday, 19 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					
17:00:00																					
22:00:00																					
Sunday, 20 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					
17:00:00																					
22:00:00																					
Monday, 21 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		Air
Time	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	
08:00:00	26	conc. o.cast	26	PBLcrete. O.cas	27.2	PBLcrete. O.cas	26.5	Conc. O.Cast.	27.3	Conc. O.cast	29.1	bitumin. O.cast	27.1	bitumin O.cast	28.4	Paver O.cast	28.1	paver. O.cast	30.4	P.paver O.cast	23.9
12:00:00	28	conc. o.cast	28.4	PBLcrete. O.cas	27.3	PBLcrete. O.cas	32	Conc. O.Cast.	31.5	Conc. O.cast	38.7	bitumin. O.cast	31.7	bitumin O.cast	33.2	Paver O.cast	32.3	paver. O.cast	33.7	P.paver O.cast	29.5
17:00:00	33	conc. o.cast	31.6	PBLcrete. O.cas	30.5	PBLcrete. O.cas	38	Conc. O.Cast.	35.9	Conc. O.cast	41.9	bitumin. O.cast	35.8	bitumin O.cast	35.6	Paver O.cast	37.8	paver. O.cast	40.2	P.paver O.cast	27.5
22:00:00	27.5	Conc. Drk.	27.5	PBLcrete. Drk	27.1	PBLcrete. Drk	28.6	Conc. Drk	29	Conc. Dark	30.2	bitumin. O.cast	26.9	bitumin. Drk	28.5	Paver O.cast	28.6	paver. O.cast	29.8	P.paver Dark	26.2
Tuesday, 22 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		Air
Time	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	
08:00:00	27.8	Conc. F.S	28.4	PBLcrete. F.S	28.7	PBLcrete. Sh.	28.7	conc. F.S.	27.6	conc. F.S.	29.9	bitumin. F.S	27.4	bitumin. F.S.	28.4	paver F.S	27.6	paver. Sh.	30.7	P.paver. F.S	27.1
12:00:00	37.3	Conc. F.S	36.8	PBLcrete. PtSh	37.7	PBLcrete. Sh.	48.2	conc. F.S.	34.6	conc. F.S.	61.9	bitumin. F.S	38.7	bitumin. F.S.	46.4	paver F.S	37.9	paver. Sh.	61.4	P.paver. F.S	33.9
17:00:00	33.2	Conc. Sh	34	PBLcrete. Sh	31.5	PBLcrete. Sh.	51.8	conc. F.S.	47.2	conc. F.S.	50.8	bitumin. F.S	35.5	bitumin. F.S.	36.3	paver F.S	51.1	paver F.S	56	P.paver. F.S	35.1
22:00:00	29	Conc. Drk.	30	PBLcrete. Drk	28.1	PBLcrete. Drk	33.6	Conc. Drk	32.4	Conc. Dark	32.1	bitumin. Drk	29.3	bitumin. Drk	30.1	paver F.S	32.4	Paver. Drk	33.5	P.paver Dark	26
Wednesday, 23 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		Air
Time	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	
08:00:00	30.9	Conc. F.S	32.5	PBLcrete. F.S	33.3	PBLcrete. Sh.	31.6	conc. F.S.	31.5	conc. F.S.	34.9	bitumin. F.S	39.2	bitumin. F.S.	30.4	paver F.S	35.6	paver. Sh.	35.6	P.paver. F.S	28.9
12:00:00	42.4	Conc. F.S	41.3	PBLcrete. F.S	43.9	PBLcrete. Prt Sh	42.7	conc. F.S.	39.6	conc. F.S.	54.8	bitumin. F.S	39.2	bitumin. F.S.	47.4	paver F.S	41.3	paver. Sh.	56.7	P.paver. F.S	35.2
17:00:00	32	Conc. Sh	30.7	PBLcrete. Sh	31	PBLcrete. Sh.	35.2	conc. F.S.	33.6	conc. F.S.	39.1	bitumin. F.S	39.1	bitumin. F.S.	32.8	paver F.S	35.1	paver F.S	41	P.paver. F.S	27.7
22:00:00	28.2	Conc. Drk.	27.8	PBLcrete. Drk	27.1	PBLcrete. Drk	28.3	Conc. Drk	27.9	Conc. Dark	30.2	bitumin. Drk	27.2	bitumin. Drk	27.7	Paver. Drk	27.3	Paver. Drk	30.3	P.paver Dark	25.8
Thursday, 24 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					
17:00:00																					
22:00:00																					
Friday, 25 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					
17:00:00																					
22:00:00																					
Saturday, 26 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					
17:00:00																					
22:00:00																					
Sunday, 27 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					
17:00:00																					
22:00:00																					
Monday, 28 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
08:00:00																					
12:00:00																					
17:00:00																					
22:00:00																					
Tuesday, 29 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		Air
Time	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	
08:00:00	29.7	Conc. F.S	32.7	PBLcrete. F.S	33.4	PBLcrete. Sh.	31.6	conc. F.S.	30.8	Conc. F.S	34.5	Bitumin. F.S	30.7	bitumin. F.S.	30.3	paver F.S	30.4	paver. Sh.	35.8	P.Paver F.S	26.8
12:00:00	44.9	Conc. Sh	42.7	PBLcrete. Sh	42.2	PBLcrete. Sh.	44.5	conc. F.S.	38.1	Conc F.S	59.7	bitumin. F.S	40.9	bitumin. F.S.	46.8	paver F.S	39.2	paver. Sh.	64.6	P.Paver F.S	34.5
17:00:00	40.2	Conc. Sh	41	PBLcrete. Sh	37	PBLcrete. Sh.	54.5	conc. F.S.	56.8	Conc F.S	61.7	bitumin. F.S	44.3	bitumin. F.S.	45	paver F.S	38.2	paver F.S	34.4	P.Paver F.S	34.5
22:00:00	29.5	Conc. Drk.	30.5	PBLcrete. Drk	28.5	PBLcrete. Drk	33.1	Conc. Drk	33.1	Conc. Dark	32.9	bitumin. Drk	30.7	bitumin. Drk	30.8	Paver. Drk	32.8	Paver. Drk	33.9	P.paver Dark	27.1
Wednesday, 30 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		Data Logger no. 9		Data Logger no. 10		Air
Time	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	Surface	Material	

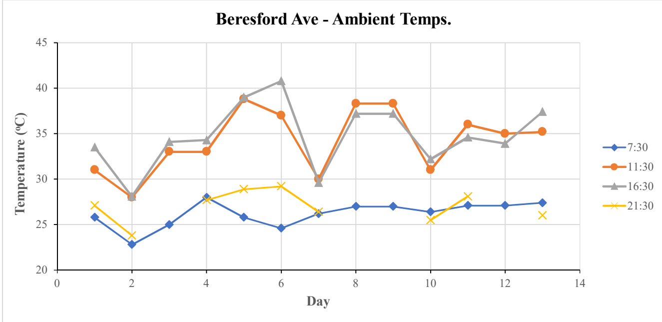
08:00:00	29.3	Conc. F.S	29.5	PBLcrete. F.S	29.8	PBLcrete. Sh.	30.9	conc. F.S.	31.1	Conc F.S	31.7	Bitumin. F.S	28.2	bitumin. F.S.	29.6	paver F.S	32	paver. Sh.	33.5	P.Paver F.S	26.3
12:00:00	46.8	Conc. Sh	47	PBLcrete. F.S	37.9	PBLcrete. Sh.	50.1	conc. F.S.	51.6	Conc F.S	55.4	Bitumin. F.S	39.4	bitumin. F.S.	47.6	paver F.S	43.4	paver. Sh.	52.5	P.Paver F.S	36.6
17:00:00	37.8	Conc. Ocast.	37.2	PBLcrete. Ocast	34.7	PBLcrete Ocast	42.9	conc. Ocast.	42.4	Conc. Ocast.	44.3	Bitumin. Ocast	37.2	bitumin. Ocast	39.4	paver O.cast.	41.2	paver Ocast.	42	P.Paver Ocast.	33.1
22:00:00	25.2	Conc. Drk.	25	PBLcrete. Drk	24.8	PBLcrete. Drk	28.8	Conc. Drk	29	Conc. Dark	30.1	bitumin. Drk	25.4	bitumin. Drk	26	Paver. Drk	27.7	Paver. Drk	31.6	P.paver Dark	25
Thursday, 31 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		**Data Logger no. 9**		**Data Logger no. 10**		**Air**
Time	**Surface**	**Material**	**Surface**	**Material**	**Surface**	**Material**	**Surface**	**Material**	**Surface**	**Material**	**Surface**	**Material**	**Surface**	**Material**	**Surface**	**Material**	**Surface**	**Material**	**Surface**	**Material**	
08:00:00	28.3	Conc. F.S	28.8	PBLcrete. F.S	28.5	PBLcrete. Sh.	29.4	conc. F.S.	28.9	Conc F.S	31.8	Bitumin. F.S	29.1	bitumin. F.S.	30.3	paver F.S	29.7	paver. Sh.	32.2	P.Paver F.S	27.8
12:00:00	38.8	Conc. Sh	37.2	PBLcrete. F.S	26.2	PBLcrete. Sh.	42.1	conc. F.S.	38.5	Conc F.S	47.8	Bitumin. F.S	39.1	bitumin. F.S.	44.1	paver F.S	42.8	paver. Sh.	48.2	P.Paver F.S	33.5
17:00:00	38.2	Conc. Sh	36.4	PBLcrete. Sh	34.3	PBLcrete. Sh.	46.7	conc. F.S.	44.4	Conc F.S	51.2	Bitumin. F.S	39.1	bitumin. F.S.	41.3	paver F.S	45.3	paver F.S	52.5	P.Paver F.S	37.1
22:00:00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

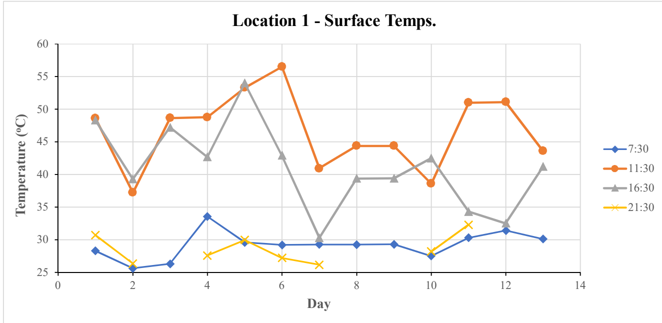
Site 5 – Beresford Avenue

SCROLL FOR ALL SITES →

LOCATION 1 (AVERAGE)







Ambient	
Time	Average Temp. (°C)
7:30:00	26.2
11:30:00	34.2
16:30:00	34.8
21:30:00	27.0

Surface	
Time	Average Temp. (°C)
7:30:00	29.2
11:30:00	46.7
16:30:00	41.1
21:30:00	28.1

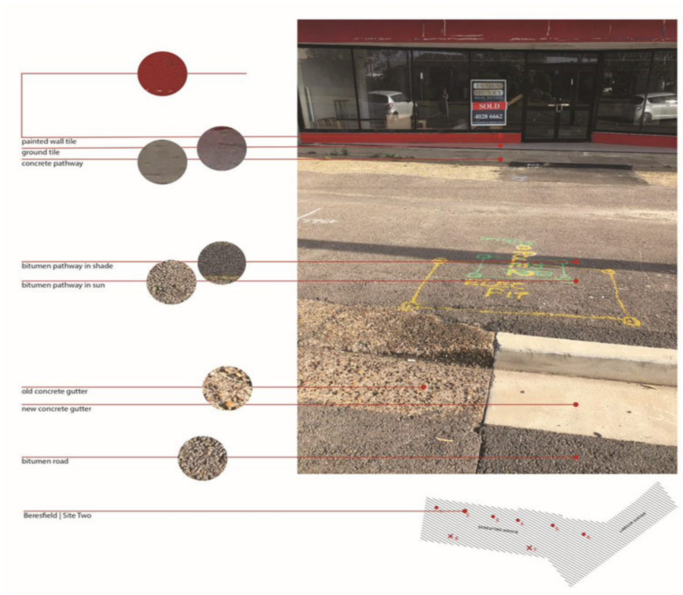
Ambient (All of Beresford Ave Sites)

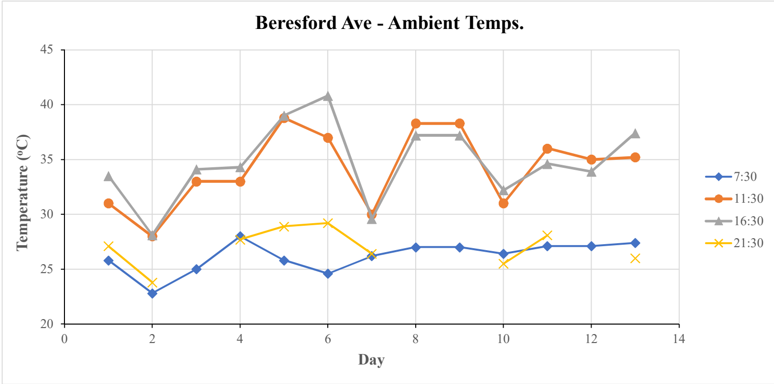
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-08	1	28, 21	25.8	31.0	33.5	27.1
Jan-10	2	27, 21	22.8	28.0	28.1	23.8
Jan-11	3	26, 19	25.0	33.0	34.1	
Jan-14	4	29, 20	28.0	33.0	34.3	27.7
Jan-15	5	34, 21	25.8	38.8	39.0	28.9
Jan-17	6	33, 20	24.6	37.0	40.8	29.2
Jan-20	7	31, 21	26.2	30.0	29.6	26.4
Jan-21	8	29, 21	27.0	38.3	37.2	
Jan-22	9	33, 22	27.0	38.3	37.2	
Jan-24	10	34, 23	26.4	31.0	32.2	25.5
Jan-29	11	33, 22	27.1	36.0	34.6	28.1
Jan-30	12	34, 23	27.1	35.0	33.9	
Jan-31	13	37, 21	27.4	35.2	37.4	26.0
Data Collection Concluded						
Average Temp. (°C)			26.2	34.2	34.8	27.0

Surface (Location 1)

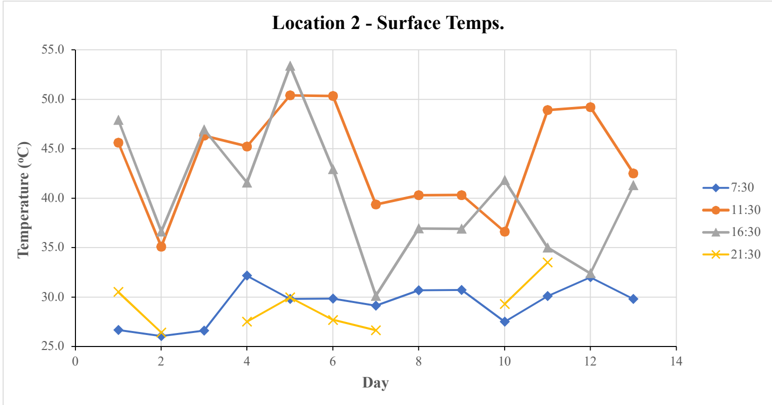
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-08	1	28, 21	28.3	48.6	48.3	30.7
Jan-10	2	27, 21	25.6	37.2	39.3	26.3
Jan-11	3	26, 19	26.3	48.7	47.2	
Jan-14	4	29, 20	33.6	48.8	42.7	27.6
Jan-15	5	34, 21	29.6	53.3	54.0	30.0
Jan-17	6	33, 20	29.2	56.5	42.9	27.2
Jan-20	7	31, 21	29.3	40.9	30.3	26.2
Jan-21	8	29, 21	29.3	44.4	39.4	
Jan-22	9	33, 22	29.3	44.4	39.4	
Jan-24	10	34, 23	27.5	38.6	42.5	28.2
Jan-29	11	33, 22	30.3	51.0	34.3	32.3
Jan-30	12	34, 23	31.4	51.1	32.5	
Jan-31	13	37, 21	30.1	43.6	41.2	24.1
Data Collection Concluded						
Average Temp. (°C)			29.2	46.7	41.1	28.1

LOCATION 2 (AVERAGE)





Ambient	
Time	Average Temp. (°C)
7:30:00	26.2
11:30:00	34.2
16:30:00	34.8
21:30:00	27.0



Surface	
Time	Average Temp. (°C)
7:30:00	29.3
11:30:00	43.9
16:30:00	40.3
21:30:00	28.2

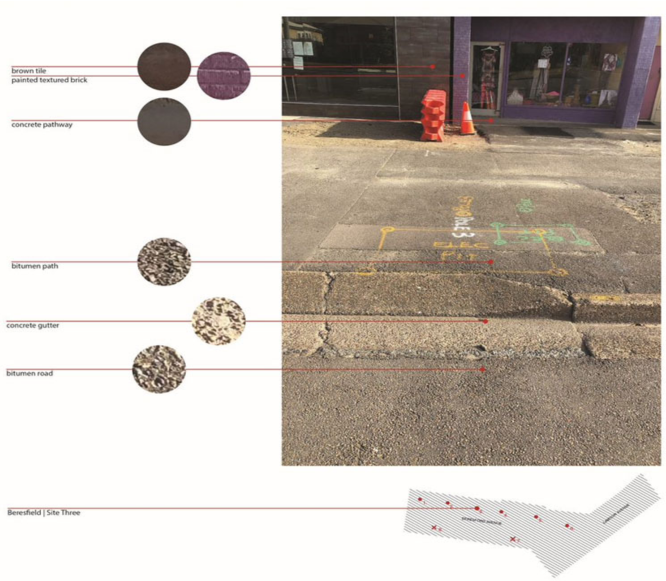
Ambient (All of Beresford Ave Sites)

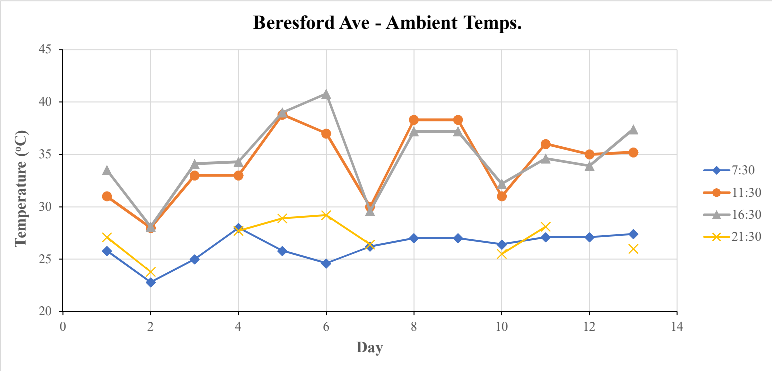
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-08	1	28, 21	25.8	31.0	33.5	27.1
Jan-10	2	27, 21	22.8	28.0	28.1	23.8
Jan-11	3	26, 19	25.0	33.0	34.1	
Jan-14	4	29, 20	28.0	33.0	34.3	27.7
Jan-15	5	34, 21	25.8	38.8	39.0	28.9
Jan-17	6	33, 20	24.6	37.0	40.8	29.2
Jan-20	7	31, 21	26.2	30.0	29.6	26.4
Jan-21	8	29, 21	27.0	38.3	37.2	
Jan-22	9	33, 22	27.0	38.3	37.2	
Jan-24	10	34, 23	26.4	31.0	32.2	25.5
Jan-29	11	33, 22	27.1	36.0	34.6	28.1
Jan-30	12	34, 23	27.1	35.0	33.9	
Jan-31	13	37, 21	27.4	35.2	37.4	26.0
Data Collection Concluded						
Average Temp. (°C)			26.2	34.2	34.8	27.0

Surface (Location 2)

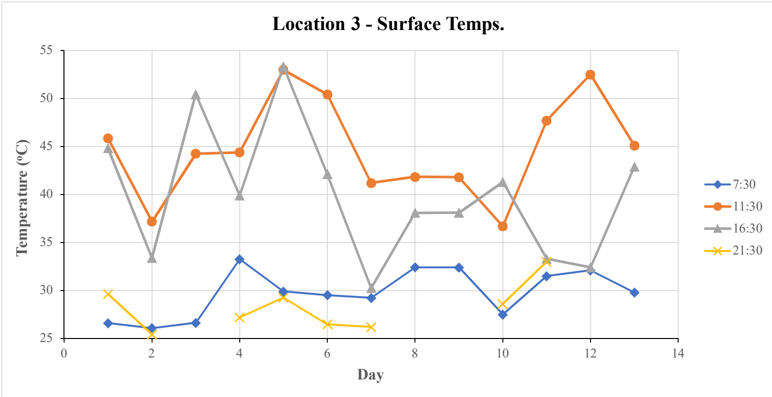
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-08	1	28, 21	26.7	45.6	47.9	30.5
Jan-10	2	27, 21	26.0	35.1	36.6	26.4
Jan-11	3	26, 19	26.6	46.3	46.9	
Jan-14	4	29, 20	32.2	45.2	41.6	27.5
Jan-15	5	34, 21	29.8	50.4	53.4	30.0
Jan-17	6	33, 20	29.8	50.3	42.9	27.7
Jan-20	7	31, 21	29.1	39.4	30.1	26.6
Jan-21	8	29, 21	30.7	40.3	36.9	
Jan-22	9	33, 22	30.7	40.3	36.9	
Jan-24	10	34, 23	27.5	36.6	41.8	29.3
Jan-29	11	33, 22	30.1	48.9	35.0	33.5
Jan-30	12	34, 23	32.0	49.2	32.4	
Jan-31	13	37, 21	29.8	42.5	41.3	22.2
Data Collection Concluded						
Average Temp. (°C)			29.3	43.9	40.3	28.2

LOCATION 3 (AVERAGE)





Ambient	
Time	Average Temp. (°C)
7:30:00	26.2
11:30:00	34.2
16:30:00	34.8
21:30:00	27.0



Surface	
Time	Average Temp. (°C)
7:30:00	29.8
11:30:00	44.8
16:30:00	40.0
21:30:00	27.4

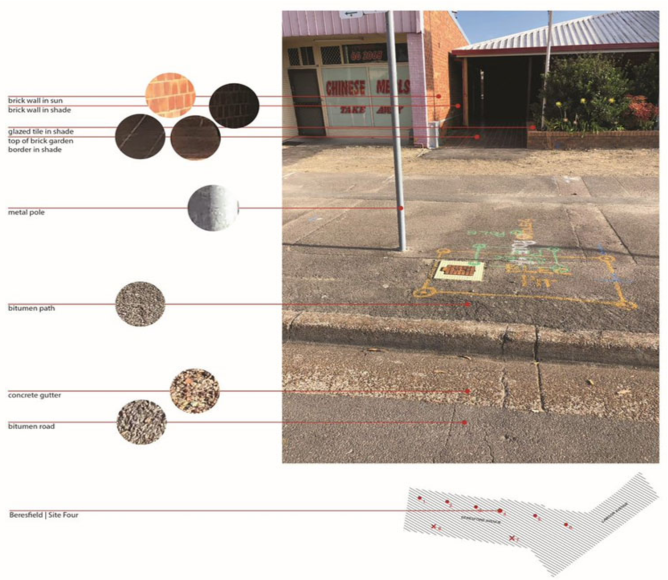
Ambient (All of Beresford Ave Sites)

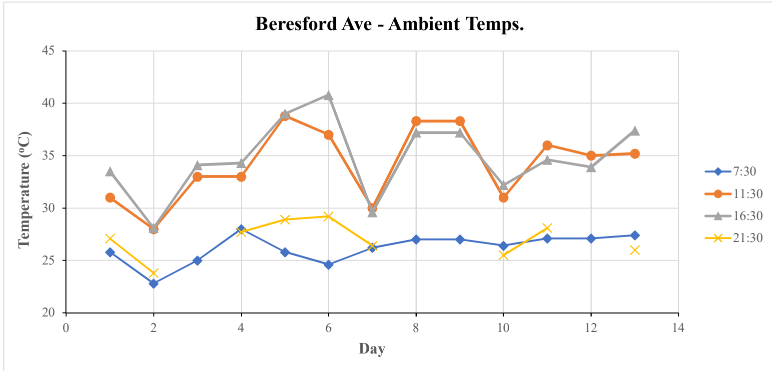
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-08	1	28, 21	25.8	31.0	33.5	27.1
Jan-10	2	27, 21	22.8	28.0	28.1	23.8
Jan-11	3	26, 19	25.0	33.0	34.1	
Jan-14	4	29, 20	28.0	33.0	34.3	27.7
Jan-15	5	34, 21	25.8	38.8	39.0	28.9
Jan-17	6	33, 20	24.6	37.0	40.8	29.2
Jan-20	7	31, 21	26.2	30.0	29.6	26.4
Jan-21	8	29, 21	27.0	38.3	37.2	
Jan-22	9	33, 22	27.0	38.3	37.2	
Jan-24	10	34, 23	26.4	31.0	32.2	25.5
Jan-29	11	33, 22	27.1	36.0	34.6	28.1
Jan-30	12	34, 23	27.1	35.0	33.9	
Jan-31	13	37, 21	27.4	35.2	37.4	26.0
Data Collection Concluded						
Average Temp. (°C)			26.2	34.2	34.8	27.0

Surface (Location 3)

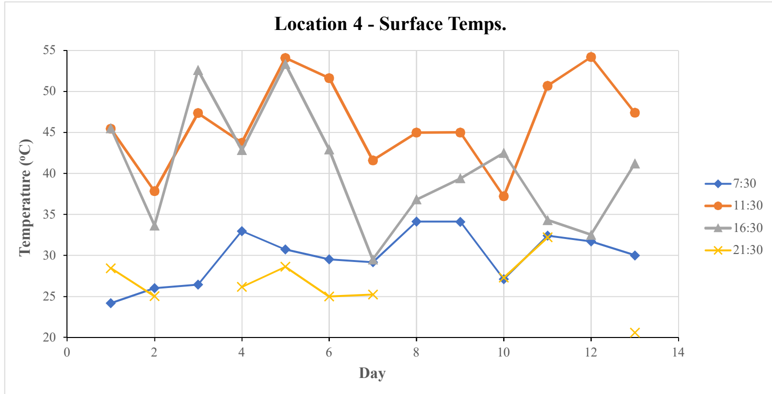
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-08	1	28, 21	26.6	45.9	44.8	29.6
Jan-10	2	27, 21	26.1	37.2	33.4	25.4
Jan-11	3	26, 19	26.6	44.3	50.4	
Jan-14	4	29, 20	33.3	44.4	39.9	27.2
Jan-15	5	34, 21	29.9	53.0	53.3	29.3
Jan-17	6	33, 20	29.5	50.4	42.1	26.5
Jan-20	7	31, 21	29.2	41.2	30.3	26.2
Jan-21	8	29, 21	32.4	41.8	38.1	
Jan-22	9	33, 22	32.4	41.8	38.1	
Jan-24	10	34, 23	27.5	36.7	41.3	28.6
Jan-29	11	33, 22	31.5	47.7	33.3	33.0
Jan-30	12	34, 23	32.1	52.5	32.4	
Jan-31	13	37, 21	29.8	45.1	42.9	21.0
Data Collection Concluded						
Average Temp. (°C)			29.8	44.8	40.0	27.4

LOCATION 4 (AVERAGE)





Ambient	
Time	Average Temp. (°C)
7:30:00	26.2
11:30:00	34.2
16:30:00	34.8
21:30:00	27.0



Surface	
Time	Average Temp. (°C)
7:30:00	29.9
11:30:00	46.2
16:30:00	40.5
21:30:00	26.5

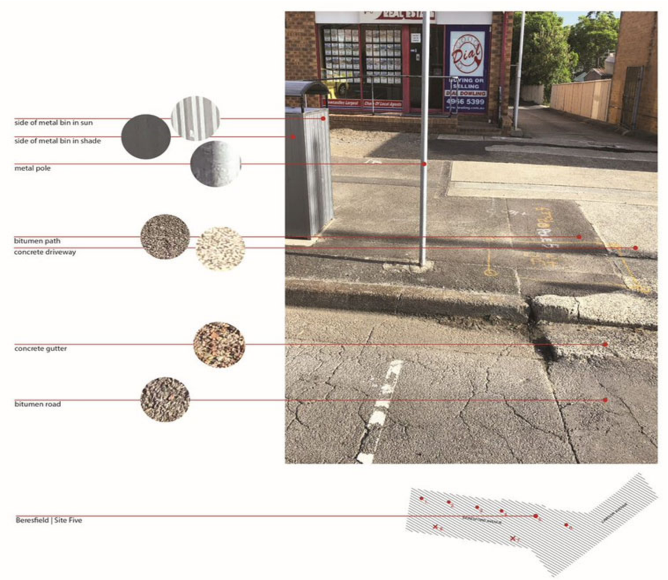
Ambient (All of Beresford Ave Sites)

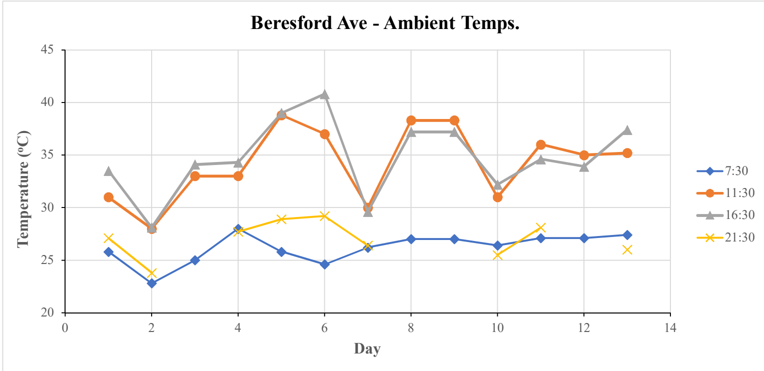
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-08	1	28, 21	25.8	31.0	33.5	27.1
Jan-10	2	27, 21	22.8	28.0	28.1	23.8
Jan-11	3	26, 19	25.0	33.0	34.1	
Jan-14	4	29, 20	28.0	33.0	34.3	27.7
Jan-15	5	34, 21	25.8	38.8	39.0	28.9
Jan-17	6	33, 20	24.6	37.0	40.8	29.2
Jan-20	7	31, 21	26.2	30.0	29.6	26.4
Jan-21	8	29, 21	27.0	38.3	37.2	
Jan-22	9	33, 22	27.0	38.3	37.2	
Jan-24	10	34, 23	26.4	31.0	32.2	25.5
Jan-29	11	33, 22	27.1	36.0	34.6	28.1
Jan-30	12	34, 23	27.1	35.0	33.9	
Jan-31	13	37, 21	27.4	35.2	37.4	26.0
Data Collection Concluded						
Average Temp. (°C)			26.2	34.2	34.8	27.0

Surface (Location 4)

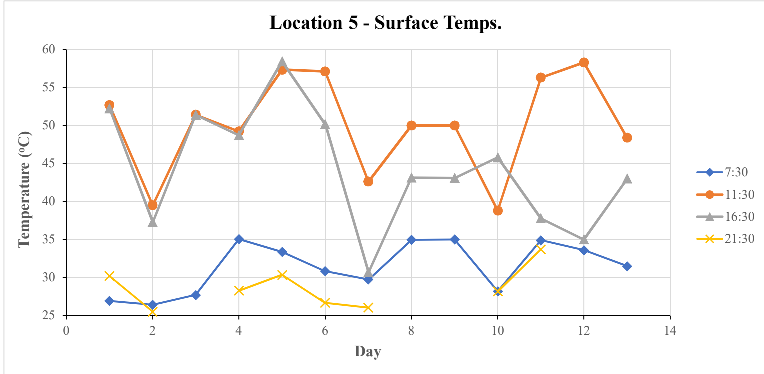
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-08	1	28, 21	24.2	45.4	45.5	28.5
Jan-10	2	27, 21	26.0	37.8	33.6	25.0
Jan-11	3	26, 19	26.4	47.4	52.6	
Jan-14	4	29, 20	33.0	43.8	42.8	26.2
Jan-15	5	34, 21	30.7	54.1	53.3	28.6
Jan-17	6	33, 20	29.5	51.6	42.9	25.0
Jan-20	7	31, 21	29.2	41.6	29.5	25.2
Jan-21	8	29, 21	34.1	45.0	36.8	
Jan-22	9	33, 22	34.1	45.0	39.4	
Jan-24	10	34, 23	27.1	37.2	42.5	27.3
Jan-29	11	33, 22	32.4	50.7	34.3	32.2
Jan-30	12	34, 23	31.7	54.2	32.5	
Jan-31	13	37, 21	30.0	47.4	41.2	20.6
Data Collection Concluded						
Average Temp. (°C)			29.9	46.2	40.5	26.5

LOCATION 5 (AVERAGE)





Ambient	
Time	Average Temp. (°C)
7:30:00	26.2
11:30:00	34.2
16:30:00	34.8
21:30:00	27.0



Surface	
Time	Average Temp. (°C)
7:30:00	31.4
11:30:00	50.1
16:30:00	44.4
21:30:00	27.9

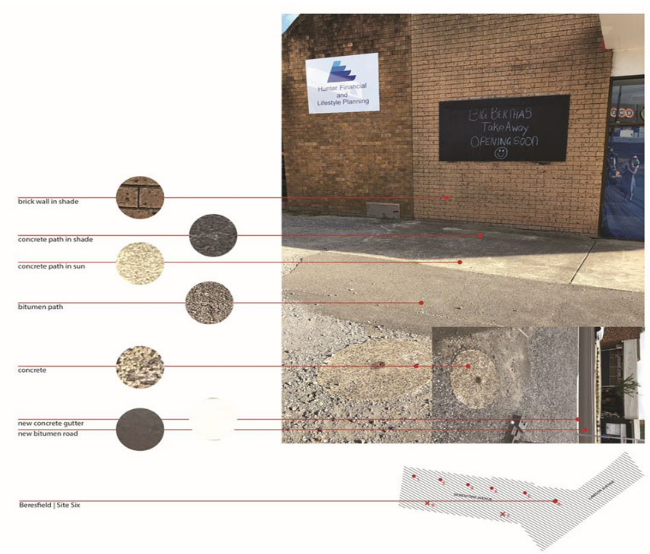
Ambient (All of Beresford Ave Sites)

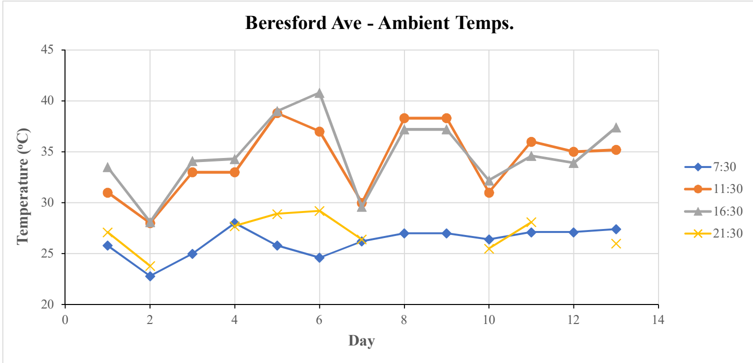
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-08	1	28, 21	25.8	31.0	33.5	27.1
Jan-10	2	27, 21	22.8	28.0	28.1	23.8
Jan-11	3	26, 19	25.0	33.0	34.1	
Jan-14	4	29, 20	28.0	33.0	34.3	27.7
Jan-15	5	34, 21	25.8	38.8	39.0	28.9
Jan-17	6	33, 20	24.6	37.0	40.8	29.2
Jan-20	7	31, 21	26.2	30.0	29.6	26.4
Jan-21	8	29, 21	27.0	38.3	37.2	
Jan-22	9	33, 22	27.0	38.3	37.2	
Jan-24	10	34, 23	26.4	31.0	32.2	25.5
Jan-29	11	33, 22	27.1	36.0	34.6	28.1
Jan-30	12	34, 23	27.1	35.0	33.9	
Jan-31	13	37, 21	27.4	35.2	37.4	26.0
Data Collection Concluded						
Average Temp. (°C)			26.2	34.2	34.8	27.0

Surface (Location 5)

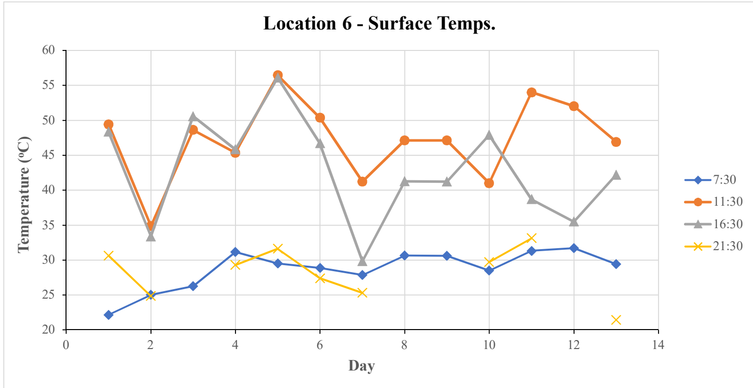
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-08	1	28, 21	26.9	52.7	52.3	30.2
Jan-10	2	27, 21	26.4	39.5	37.3	25.5
Jan-11	3	26, 19	27.7	51.4	51.4	
Jan-14	4	29, 20	35.1	49.2	48.7	28.3
Jan-15	5	34, 21	33.4	57.3	58.4	30.4
Jan-17	6	33, 20	30.8	57.1	50.2	26.7
Jan-20	7	31, 21	29.7	42.6	30.7	26.1
Jan-21	8	29, 21	35.0	50.0	43.1	
Jan-22	9	33, 22	35.0	50.0	43.1	
Jan-24	10	34, 23	28.2	38.8	45.8	28.2
Jan-29	11	33, 22	34.9	56.3	37.8	33.7
Jan-30	12	34, 23	33.6	58.3	35.0	
Jan-31	13	37, 21	31.5	48.4	43.0	22.4
Data Collection Concluded						
Average Temp. (°C)			31.4	50.1	44.4	27.9

LOCATION 6 (AVERAGE)





Ambient	
Time	Average Temp. (°C)
7:30:00	26.2
11:30:00	34.2
16:30:00	34.8
21:30:00	27.0



Surface	
Time	Average Temp. (°C)
7:30:00	28.7
11:30:00	47.3
16:30:00	42.9
21:30:00	28.1

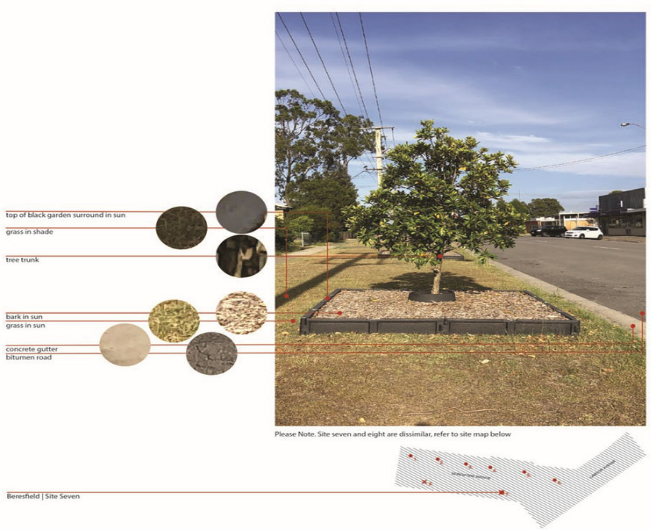
Ambient (All of Beresford Ave Sites)

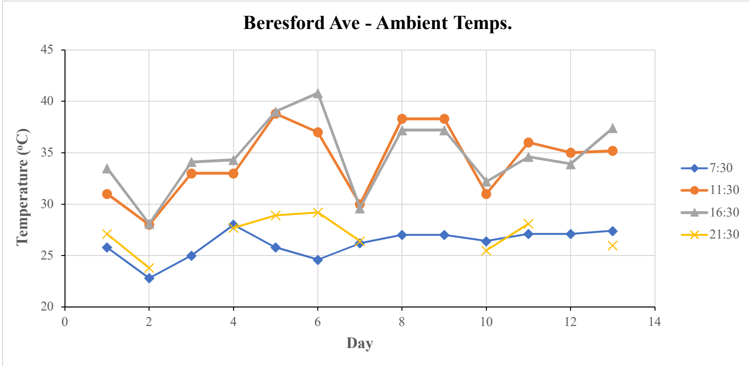
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-08	1	28, 21	25.8	31.0	33.5	27.1
Jan-10	2	27, 21	22.8	28.0	28.1	23.8
Jan-11	3	26, 19	25.0	33.0	34.1	
Jan-14	4	29, 20	28.0	33.0	34.3	27.7
Jan-15	5	34, 21	25.8	38.8	39.0	28.9
Jan-17	6	33, 20	24.6	37.0	40.8	29.2
Jan-20	7	31, 21	26.2	30.0	29.6	26.4
Jan-21	8	29, 21	27.0	38.3	37.2	
Jan-22	9	33, 22	27.0	38.3	37.2	
Jan-24	10	34, 23	26.4	31.0	32.2	25.5
Jan-29	11	33, 22	27.1	36.0	34.6	28.1
Jan-30	12	34, 23	27.1	35.0	33.9	
Jan-31	13	37, 21	27.4	35.2	37.4	26.0
Data Collection Concluded						
Average Temp. (°C)			26.2	34.2	34.8	27.0

Surface (Location 6)

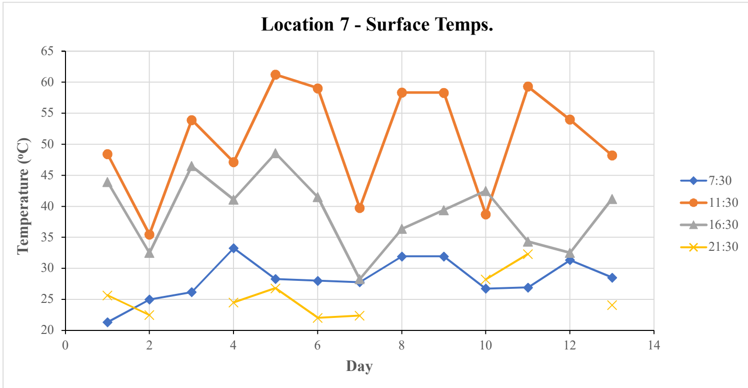
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-08	1	28, 21	22.2	49.4	48.3	30.6
Jan-10	2	27, 21	25.0	34.9	33.4	24.9
Jan-11	3	26, 19	26.3	48.6	50.6	
Jan-14	4	29, 20	31.1	45.3	45.8	29.3
Jan-15	5	34, 21	29.5	56.5	56.1	31.6
Jan-17	6	33, 20	28.9	50.4	46.7	27.4
Jan-20	7	31, 21	27.9	41.2	29.9	25.3
Jan-21	8	29, 21	30.6	47.1	41.2	
Jan-22	9	33, 22	30.6	47.1	41.2	
Jan-24	10	34, 23	28.5	41.0	47.9	29.7
Jan-29	11	33, 22	31.3	54.0	38.7	33.1
Jan-30	12	34, 23	31.7	52.0	35.5	
Jan-31	13	37, 21	29.4	46.9	42.2	21.4
Data Collection Concluded						
Average Temp. (°C)			28.7	47.3	42.9	28.1

LOCATION 7 (AVERAGE)





Ambient	
Time	Average Temp. (°C)
7:30:00	26.2
11:30:00	34.2
16:30:00	34.8
21:30:00	27.0



Surface	
Time	Average Temp. (°C)
7:30:00	28.2
11:30:00	50.9
16:30:00	39.1
21:30:00	25.4

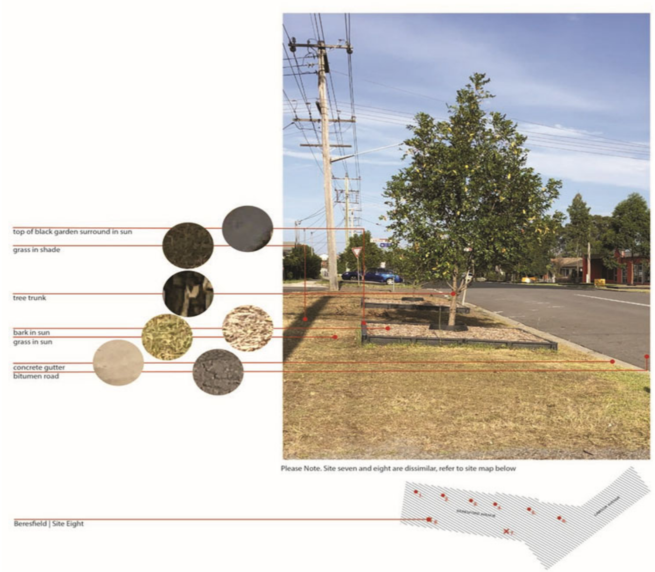
Ambient (All of Beresford Ave Sites)

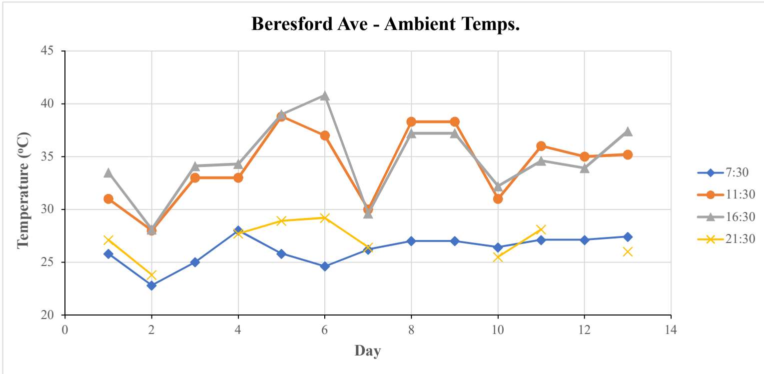
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-08	1	28, 21	25.8	31.0	33.5	27.1
Jan-10	2	27, 21	22.8	28.0	28.1	23.8
Jan-11	3	26, 19	25.0	33.0	34.1	
Jan-14	4	29, 20	28.0	33.0	34.3	27.7
Jan-15	5	34, 21	25.8	38.8	39.0	28.9
Jan-17	6	33, 20	24.6	37.0	40.8	29.2
Jan-20	7	31, 21	26.2	30.0	29.6	26.4
Jan-21	8	29, 21	27.0	38.3	37.2	
Jan-22	9	33, 22	27.0	38.3	37.2	
Jan-24	10	34, 23	26.4	31.0	32.2	25.5
Jan-29	11	33, 22	27.1	36.0	34.6	28.1
Jan-30	12	34, 23	27.1	35.0	33.9	
Jan-31	13	37, 21	27.4	35.2	37.4	26.0
Data Collection Concluded						
Average Temp. (°C)			26.2	34.2	34.8	27.0

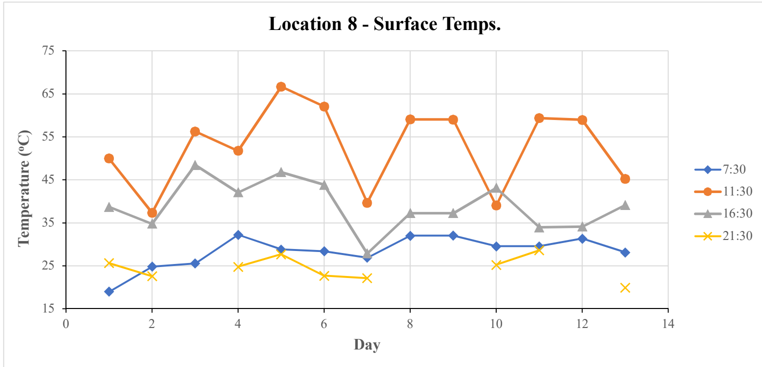
Surface (Location 7)

Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-08	1	28, 21	21.3	48.4	43.9	25.7
Jan-10	2	27, 21	25.0	35.5	32.5	22.5
Jan-11	3	26, 19	26.1	53.9	46.5	
Jan-14	4	29, 20	33.2	47.1	41.1	24.5
Jan-15	5	34, 21	28.3	61.2	48.6	26.8
Jan-17	6	33, 20	28.0	59.0	41.5	22.0
Jan-20	7	31, 21	27.7	39.7	28.3	22.4
Jan-21	8	29, 21	31.9	58.3	36.4	
Jan-22	9	33, 22	31.9	58.3	39.4	
Jan-24	10	34, 23	26.7	38.7	42.5	28.2
Jan-29	11	33, 22	26.9	59.3	34.3	32.3
Jan-30	12	34, 23	31.3	54.0	32.5	
Jan-31	13	37, 21	28.5	48.2	41.2	24.1
Data Collection Concluded						
Average Temp. (°C)			28.2	50.9	39.1	25.4

LOCATION 8 (AVERAGE)







Ambient	
Time	Average Temp. (°C)
7:30:00	26.2
11:30:00	34.2
16:30:00	34.8
21:30:00	27.0

Surface	
Time	Average Temp. (°C)
7:30:00	28.3
11:30:00	52.6
16:30:00	39.0
21:30:00	24.3

Ambient (All of Beresford Ave Sites)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Ambient Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-08	1	28, 21	25.8	31.0	33.5	27.1
Jan-10	2	27, 21	22.8	28.0	28.1	23.8
Jan-11	3	26, 19	25.0	33.0	34.1	
Jan-14	4	29, 20	28.0	33.0	34.3	27.7
Jan-15	5	34, 21	25.8	38.8	39.0	28.9
Jan-17	6	33, 20	24.6	37.0	40.8	29.2
Jan-20	7	31, 21	26.2	30.0	29.6	26.4
Jan-21	8	29, 21	27.0	38.3	37.2	
Jan-22	9	33, 22	27.0	38.3	37.2	
Jan-24	10	34, 23	26.4	31.0	32.2	25.5
Jan-29	11	33, 22	27.1	36.0	34.6	28.1
Jan-30	12	34, 23	27.1	35.0	33.9	
Jan-31	13	37, 21	27.4	35.2	37.4	26.0
Data Collection Concluded						
Average Temp. (°C)			26.2	34.2	34.8	27.0

Surface (Location 8)						
Date	Day	Weather Forecast (Max, Min) (°C)	Time/Surface Temp. (°C)			
			7:30:00	11:30:00	16:30:00	21:30:00
Jan-08	1	28, 21	19.0	50.0	38.7	25.6
Jan-10	2	27, 21	24.8	37.3	34.8	22.5
Jan-11	3	26, 19	25.5	56.2	48.4	
Jan-14	4	29, 20	32.2	51.8	42.0	24.8
Jan-15	5	34, 21	28.8	66.7	46.8	27.7
Jan-17	6	33, 20	28.4	62.1	43.8	22.7
Jan-20	7	31, 21	26.9	39.6	27.8	22.1
Jan-21	8	29, 21	32.0	59.0	37.2	
Jan-22	9	33, 22	32.0	59.0	37.2	
Jan-24	10	34, 23	29.5	39.0	43.1	25.2
Jan-29	11	33, 22	29.5	59.3	33.9	28.6
Jan-30	12	34, 23	31.3	58.9	34.1	
Jan-31	13	37, 21	28.1	45.2	39.1	19.9
Data Collection Concluded						
Average Temp. (°C)			28.3	52.6	39.0	24.3

Site 5 – Beresford Avenue																	
Date	Temperature Readings (°C)																
Monday, 7 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		(Rainy day)
Time	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	
07:30:00																	
11:30:00																	
16:30:00																	
21:30:00																	
Tuesday, 8 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		(Sunny, 28/21)
Time	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	
07:19:00 - 07:40:00	28.3	25.8	26.7	25.8	26.6	25.8	24.2	25.8	26.9	25.8	22.2	25.8	21.3	25.8	19.0	25.8	
12:25:00 -12:38:00	48.6	31.0	45.6	31.0	45.9	31.0	45.4	31.0	52.7	31.0	49.4	31.0	48.4	31.0	50.0	31.0	
17:45:00 -17:57:00	48.3	33.5	47.9	33.5	44.8	33.5	45.5	33.5	52.3	33.5	48.3	33.5	43.9	33.5	38.7	33.5	
21:10:00 - 21:20:00	30.7	27.1	30.5	27.1	29.6	27.1	28.5	27.1	30.2	27.1	30.6	27.1	25.7	27.1	25.6	27.1	
Wednesday, 9 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		(Sunny, 30/22)
Time	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	
07:30:00																	
11:30:00																	
16:30:00																	
21:30:00																	
Thursday, 10 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		(Cloudy, 27/21)
Time	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	
07:19:00 - 07:40:00	25.6	22.8	26.0	22.8	26.1	22.8	26.0	22.8	26.4	22.8	25.0	22.8	25.0	22.8	24.8	22.8	
12:25:00 -12:38:00	37.2	28.0	35.1	28.0	37.2	28.0	37.8	28.0	39.5	28.0	34.9	28.0	35.5	28.0	37.3	28.0	
17:45:00 -17:57:00	39.3	28.1	36.6	28.1	33.4	28.1	33.6	28.1	37.3	28.1	33.4	28.1	32.5	28.1	34.8	28.1	
21:10:00 - 21:20:00	26.3	23.8	26.4	23.8	25.4	23.8	25.0	23.8	25.5	23.8	24.9	23.8	22.5	23.8	22.5	23.8	
Friday, 11 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		(Cloudy, 26/19)
Time	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	
07:19:00 - 07:40:00	26.3	25.0	26.6	25.0	26.6	25.0	26.4	25.0	27.7	25.0	26.3	25.0	26.1	25.0	25.5	25.0	
12:25:00 -12:38:00	48.7	33.0	46.3	33.0	44.3	33.0	47.4	33.0	51.4	33.0	48.6	33.0	53.9	33.0	56.2	33.0	
17:45:00 -17:57:00	47.2	34.1	46.9	34.1	50.4	34.1	52.6	34.1	51.4	34.1	50.6	34.1	46.5	34.1	48.4	34.1	
21:10:00 - 21:20:00																	
Saturday, 12 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		(Sunny, 33/20)
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
07:30:00																	
11:30:00																	
16:30:00																	
21:30:00																	
Sunday, 13 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		(Sunny, 31/21)
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	
07:30:00																	
11:30:00																	
16:30:00																	
21:30:00																	
Monday, 14 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		(Sunny/cloud, 29/20) (Did rain)
Time	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	
07:30:00	33.6	28.0	32.2	28.0	33.3	28.0	33.0	28.0	35.1	28.0	31.1	28.0	33.2	28.0	32.2	28.0	
11:30:00	48.8	33.0	45.2	33.0	44.4	33.0	43.8	33.0	49.2	33.0	45.3	33.0	47.1	33.0	51.8	33.0	
16:30:00	42.7	34.3	41.6	34.3	39.9	34.3	42.8	34.3	48.7	34.3	45.8	34.3	41.1	34.3	42.0	34.3	
21:30:00	27.6	27.7	27.5	27.7	27.2	27.7	26.2	27.7	28.3	27.7	29.3	27.7	24.5	27.7	24.8	27.7	
Tuesday, 15 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		(Sunny, 34/21)
Time	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	
07:30:00	29.6	25.8	29.8	25.8	29.9	25.8	30.7	25.8	33.4	25.8	29.5	25.8	28.3	25.8	28.8	25.8	
11:30:00	53.3	38.8	50.4	38.8	53.0	38.8	54.1	38.8	57.3	38.8	56.5	38.8	61.2	38.8	66.7	38.8	
16:30:00	54.0	39.0	53.4	39.0	53.3	39.0	53.3	39.0	58.4	39.0	56.1	39.0	48.6	39.0	46.8	39.0	
21:30:00	30.0	28.9	30.0	28.9	29.3	28.9	28.6	28.9	30.4	28.9	31.6	28.9	26.8	28.9	27.7	28.9	
Wednesday, 16 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		
Time	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	Surface	Air	

07:30:00																	(Sunny, 35/22)
11:30:00																	
16:30:00																	
21:30:00																	
Thursday, 17 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		
Time	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	
07:30:00	29.2	24.6	29.8	24.6	29.5	24.6	29.5	24.6	30.8	24.6	28.9	24.6	28.0	24.6	28.4	24.6	
11:30:00	56.5	37.0	50.3	37.0	50.4	37.0	51.6	37.0	57.1	37.0	50.4	37.0	59.0	37.0	62.1	37.0	
16:30:00	42.9	40.8	42.9	40.8	42.1	40.8	42.9	40.8	50.2	40.8	46.7	40.8	41.5	40.8	43.8	40.8	
21:30:00	27.2	29.2	27.7	29.2	26.5	29.2	25.0	29.2	26.7	29.2	27.4	29.2	22.0	29.2	22.7	29.2	
Friday, 18 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	
07:30:00																	
11:30:00																	
16:30:00																	
21:30:00																	
Saturday, 19 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		
Time	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	**Surface**	**Air**	
07:30:00																	
11:30:00																	
16:30:00																	
21:30:00																	
Sunday, 20 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		
Time	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	
07:30:00	29.3	26.2	29.1	26.2	29.2	26.2	29.2	26.2	29.7	26.2	27.9	26.2	27.7	26.2	26.9	26.2	
11:30:00	40.9	30.0	39.4	30.0	41.2	30.0	41.6	30.0	42.6	30.0	41.2	30.0	39.7	30.0	39.6	30.0	
16:30:00	30.3	29.6	30.1	29.6	30.3	29.6	29.5	29.6	30.7	29.6	29.9	29.6	28.3	29.6	27.8	29.6	
21:30:00	26.2	26.4	26.6	26.4	26.2	26.4	25.2	26.4	26.1	26.4	25.3	26.4	22.4	26.4	22.1	26.4	
Monday, 21 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		
Time	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	
07:30:00	29.3	27.0	30.7	27.0	32.4	27.0	34.1	27.0	35.0	27.0	30.6	27.0	31.9	27.0	32.0	27.0	(Cloudy, 29/21)
11:30:00	44.4	38.3	40.3	38.3	41.8	38.3	45.0	38.3	50.0	38.3	47.1	38.3	58.3	38.3	59.0	38.3	
16:30:00	39.4	37.2	36.9	37.2	38.1	37.2	36.8	37.2	43.1	37.2	41.2	37.2	36.4	37.2	37.2	37.2	
21:30:00																	
Tuesday, 22 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		
Time	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	
07:30:00	29.3	27.0	30.7	27.0	32.4	27.0	34.1	27.0	35.0	27.0	30.6	27.0	31.9	27.0	32.0	27.0	(Sunny, 33/22)
11:30:00	44.4	38.3	40.3	38.3	41.8	38.3	45.0	38.3	50.0	38.3	47.1	38.3	58.3	38.3	59.0	38.3	
16:30:00	39.4	37.2	36.9	37.2	38.1	37.2	36.8	37.2	43.1	37.2	41.2	37.2	36.4	37.2	37.2	37.2	
21:30:00																	
Wednesday, 23 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		
Time	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	
07:30:00																	
11:30:00																	
16:30:00																	
21:30:00																	
Thursday, 24 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		
Time	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	
07:30:00	27.5	26.4	27.5	26.4	27.5	26.4	27.1	26.4	28.2	26.4	28.5	26.4	26.7	26.4	29.5	26.4	(Sunny, 34/23)
11:30:00	38.6	31.0	36.6	31.0	36.7	31.0	37.2	31.0	38.8	31.0	41.0	31.0	38.7	31.0	39.0	31.0	
16:30:00	42.5	32.2	41.8	32.2	41.3	32.2	41.0	32.2	45.8	32.2	47.9	32.2	41.5	32.2	43.1	32.2	
21:30:00	28.2	25.5	29.3	25.5	28.6	25.5	27.3	25.5	28.2	25.5	29.7	25.5	24.7	25.5	25.2	25.5	
Friday, 25 January 2019	**Data Logger no.1**		**Data Logger no. 2**		**Data Logger no. 3**		**Data Logger no. 4**		**Data Logger no. 5**		**Data Logger no. 6**		**Data Logger no. 7**		**Data Logger no.8**		
Time	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	**Surface (average)**	**Air**	
07:30:00																	
11:30:00																	
16:30:00																	
21:30:00																	

Saturday, 26 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8	
Time	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air
07:30:00																
11:30:00																
16:30:00																
21:30:00																

Sunday, 27 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8	
Time	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air
07:30:00																
11:30:00																
16:30:00																
21:30:00																

Monday, 28 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8	
Time	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air
07:30:00																
11:30:00																
16:30:00																
21:30:00																

Tuesday, 29 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		
Time	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	
07:30:00	30.3	27.1	30.1	27.1	31.5	27.1	32.4	27.1	34.9	27.1	31.3	27.1	26.9	27.1	29.5	27.1	(Sunny, 33/22)
11:30:00	51.0	36.0	48.9	36.0	47.7	36.0	50.7	36.0	56.3	36.0	54.0	36.0	59.3	36.0	59.3	36.0	
16:30:00	34.3	34.6	35.0	34.6	33.3	34.6	34.1	34.6	37.8	34.6	38.7	34.6	36.1	34.6	33.9	34.6	
21:30:00	32.3	28.1	33.5	28.1	33.0	28.1	32.2	28.1	33.7	28.1	33.1	28.1	29.5	28.1	28.6	28.1	

Wednesday, 30 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		
Time	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	
07:30:00	31.4	27.1	32.0	27.1	32.1	27.1	31.7	27.1	33.6	27.1	31.7	27.1	31.3	27.1	31.3	27.1	(Sunny/Cloudy, 34/23)
11:30:00	51.1	35.0	49.2	35.0	52.5	35.0	54.2	35.0	58.3	35.0	52.0	35.0	54.0	35.0	58.9	35.0	
16:30:00	32.5	33.9	32.4	33.9	32.4	33.9	34.2	33.9	35.0	33.9	35.5	33.9	34.3	33.9	34.1	33.9	
21:30:00																	

Thursday, 31 January 2019	Data Logger no.1		Data Logger no. 2		Data Logger no. 3		Data Logger no. 4		Data Logger no. 5		Data Logger no. 6		Data Logger no. 7		Data Logger no.8		
Time	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	Surface (average)	Air	
07:30:00	30.1	27.4	29.8	27.4	29.8	27.4	30.0	27.4	31.5	27.4	29.4	27.4	28.5	27.4	28.1	27.4	(Sunny, 37/21)
11:30:00	43.6	35.2	42.5	35.2	45.1	35.2	47.4	35.2	48.4	35.2	46.9	35.2	48.2	35.2	45.2	35.2	
16:30:00	41.2	37.4	41.3	37.4	42.9	37.4	42.2	37.4	43.0	37.4	42.2	37.4	37.7	37.4	39.1	37.4	
21:30:00	24.1	26.0	22.2	26.0	21.0	26.0	20.6	26.0	22.4	26.0	21.4	26.0	19.7	26.0	19.9	26.0	

Temperature Readings (°C)

Date	Time	1 Green bench	1.1 shaded bitumen path	1.2 Bitumen path	1.3 concrete around pole	1.4 metal pole itself	1.5 concrete gutter	1.6 bitumen road	1.7 concrete sun	1.8 concrete shade	1.9 tiles on vinnies	average @ data poles	2.1 bitumen pathway sun	2.2 bitumen pathway shade	2.3 concrete gutter new	2.4 concrete gutter old	2.5 bitumen road	2.6 concrete path sun	2.7 concrete path shade	2.8 shopfront wall tile ground	2.9 shopfront wall tile wall	average @ data poles
Tuesday, 8 January 2019	07:19:00 AM-07:40:00 AM	27.3	26.1	28.4	28	32	29.3	29.9	28.3	27.1	26.4	28.3	27.3	25.5	27.2	27.7	28	27.2	26.3	25.9	24.8	26.7
	12:25:00 PM-12:38:00 PM	60.8	40	60.2	51.3	45	56.2	58		32.3	33.3	48.6	58.7		50.5	50.3	59.1		33.8	33.2	33.7	45.6
	17:45:00 PM-17:57:00 PM	48.8	48	54.4	48.4	48.9	53.2	52.8	40.7		39.2	48.3	56.9		51.4	51	55.9	42.3		38.8	39.1	47.9
	9:10:00 PM-09:20:00 PM	24		33.2	32	29.2	34.3	33.3	29		30.5	30.7	32.7		32.4	32.3	31.7	28.1		27.9	28.5	30.5
Thursday, 10 January 2019	07:34:00 AM-07:46:00 AM	24.4		25.2	25.2	25.9	27.1	27.8	25.1		24.2	25.6		26.9	27.1	26.1	26.9	25		25.1	25.2	26.0
	12:23:00 PM-12:41:00 PM	44.5		40.3	36.1	36.1	39.7	41.7	30.2		29.1	37.2		42.3	36.9	36.3	41.3		30.3	28.8	29.8	35.1
	17:35:00	43.3	36.6	43.1	39.8	38.5	42.7	44.1	33.8		31.6	39.3	44		39.5	39.2	43.5	32		28.8	29.3	36.6
	21:04:00	21.3		28.2	27.1	24.2	29.3	29.7	25.7		25.1	26.3	28.2		28.3	27.9	28	24.5		24.3	23.7	26.4
Friday, 11 January 2019	07:40:00	25.5		26.7	26.4	26.5	27.7	28.1	25.1		24.4	26.3	27.6		27.5	27.8	27.8	25.4		25.1	25	26.6
	12:40:00	70.6	37.3	61.1	51.4	37	56.5	58.6		33.1	32.4	48.7	61.9		52.9	53.3	61.3		31.6	31.2	31.9	46.3
	17:30:00	52.6	36.4	62	51	38.9	54	57	42		31	47.2	59.9		52	52	59.8	39.9		32	33	46.9
	21:00:00																					
Monday, 14 January 2019	07:48:00	36.7	30.8	35.9	33.7	33.8	35	37.7		29.9	28.5	33.6	33.3		34.8	33.3	36.9		29.2	28.6	29	32.2
	12:40:00	72.5	38.6	59.8	51.4	41.1	54.6	57.7		31.7	31.6	48.8	59.3		51.1	52.3	61		31.6	30.3	31	45.2
	17:37:00	47.2	39	49.7	44.7	35.8	49.2	49.4	35		33.9	42.7	51.7		45.2	44.4	49.5	36.1		31.6	32.5	41.6
	21:23:00	20.4		28.9	29.2	26.9	30.9	30.7	26.2		27.4	27.6	29.7		29	28.6	28.8	25.3		25.4	25.7	27.5
Tuesday, 15 January 2019	07:30:00	29.4	27.5	32.4	29.9	31.7	29.6	32.2	28.5	27.8	26.9	29.6	30.9	29.5	30	31.4	32.7	30	27.8	27.9	28	29.8
	12:45:00	74.8	40.4	68.8	57	40.8	62.9	65.3		34.5	35.3	53.3	66.1		58.5	60.3	64		34.1	34.3	35.5	50.4
	17:00:00	58	49.9	62.3	56.6	54.3	62.8	62.9	45.2	42.9	45	54.0	65.6		60.8	60.1	63.9	46.5	42.7	43	44.3	53.4
	21:30:00	22.8		32.4	31.7	27.9	33.6	33.5	27.7		30.2	30.0	32.5		32.5	32.3	30.6	27.2		27.4	27.3	30.0
Thursday, 17 January 2019	07:30:00	25.3		29.4	29.9	30.3	31.4	32.8	27.5		27	29.2	31.1		31.5	32	31.4	27.9		27.8	27.2	29.8
	12:55:00	79.7	43.5	69.6	62.3	48.8	65.7	66.7		36	36.4	56.5	67.6		58.4	59.9	63.8		34.2	33.7	34.7	50.3
	17:37:00	48.1	46.3	51.5	46.3	39.6	50	50.3	34.5	28.4	34.1	42.9	53.9		48.9	48.4	51.3	35.4		30.5	32.1	42.9
	21:50:00	18.8		30	29.8	24.3	31.3	30.8	25.2		27.4	27.2	29.4		29.6	30.4	29.5	24.8		25.1	25	27.7
Monday, 21 January 2019	07:50:00	30.3		29.9	28.9	27.5	30.6	32	27.9		27	29.3	30.5		30.6	29.6	31	27.6		27.4	27.2	29.1
	12:55:00	51.3		46	42	34.6	44.3	45.6	32.3		31.3	40.9	47.5		42.9	42.8	45.9	32.7		31.3	32.4	39.4
	17:30:00	30		32.5	31	28.5	33.1	33.2	26.7		27.2	30.3	33.1		31.8	31.8	33.1	27.5		26.4	27.1	30.1
	21:00:00	20.1		26.6	26.9	26.2	28.2	28.4	26.2		26.7	26.2	27.4		27.6	27.6	26.7	25.8		25.7	25.6	26.6
Tuesday, 22 January 2019	07:50:00	30.7	27.2	29.5	28.8	30.5	30.4	31.5		27.6	27.1	29.3	31.2	30.3	31.2	32.2	33		29.4	29.1	29.1	30.7
	12:00:00	69.9	31.5	55.4	48.1	35.9	51.5	53.8		26.4	27	44.4	57.9		45.8	47.2	50.9		26.8	26.2	27.2	40.3
	18:30:00	40.1	42.1	43.9	40.9	33.7	44.3	43.1	33.3		33	39.4	45.4		38.9	38.9	41.8	32.1		30.5	30.8	36.9
	21:00:00											#DIV/0!										#DIV/0!
Wednesday, 23 January 2019	07:30:00	25.5		28.3	27.9	27.2	29.4	29.8		26.5	25.6	27.5	28.7		27.4	29	28.6		26.5	26.4	26	27.5
	12:45:00	42.5		42.6	40.2	35.3	42.3	43.3		31.5	31.3	38.6		41.5	38.9	39.9	43		31.1	30.2	31.6	36.6
	17:38:00	47		48.3	44.4	41.7	47.5	47.7	36.9	33.5	35.6	42.5	50.8		46.3	46.6	48.2	39.2	34.6	33.9	34.7	41.8
	9:42:00pm	21.7		30.2	29.9	26.3	31.2	31.1	27.5		28	28.2	30.7		30.7	30.9	30.7	27.7		27.1	27.5	29.3
DATE	07:30:00											#DIV/0!										#DIV/0!
	12:00:00											#DIV/0!										#DIV/0!
	17:30:00											#DIV/0!										#DIV/0!
	21:00:00											#DIV/0!										#DIV/0!
DATE	07:30:00											#DIV/0!										#DIV/0!
	12:00:00											#DIV/0!										#DIV/0!
	17:30:00											#DIV/0!										#DIV/0!
	21:00:00											#DIV/0!										#DIV/0!

Data Logger no. 3 - pole 3 / Data Logger no. 4 - pole 4 / Data Logger no. 5 - pole 5

Date	Time	3 bitumen pathway	3 concrete gutter	3 bitumen road	brown tile on shop wall sun	brown tile on shop wall shade	purple painted brick on shop wall sun	purple painted brick on shop wall shade	pavement in front of purple shop sun	pavement in front of purple shop shade	divided by no. of	4 bitumen path	4 metal pole	4 concrete gutter	4 bitumen road	post office tile on ground sun	post office tile on ground shade	post office brick on wall sun	post office brick on wall shade	brick around garden sun	brick around garden shade	divided by no. of	5 bitumen path	5 concrete driveway	5 concrete gutter	5 bitumen road	5 metal pole	side of metal bin sun	side of metal bin shade	divided by no. of
Monday, 21 January 2019	07:50:00	30.8	30.4	31.8	27.6		27.1		27.7		29.2	30.2	28.6	30.4	31	29.1		27.7		27.2		29.2	30.2	29.7	29.4	31.5	28.9	28.7		29.7
	12:55:00	48.1	44.9	45.5	38.6		35.6		34.5		41.2	47.2	38.4	43.2	45.3	40		36.7		40.4		41.6	46.3	43.1	43.3	46.7	36.1	40.2		42.6
	17:30:00	33.1	32.1	32.5	27.7		27.9		28.3		30.3	32.7	27	31.5	31.6	27.8		27.4		28.5		29.5	32.6	31.3	32	32.2	28.7	27.2		30.7
	21:00:00	27.5	27.4	27.2	25		24.4		25.7		26.2	26.6	23.4	27.3	26.2	25		25.3		22.7		25.2	26.9	26.6	27	27.3	25.5	23		26.1
Tuesday, 22 January 2019	07:50:00	34.2	32.5	34.9		30.9		31.7		30.3	32.4	34.5	37.4	34.3	34.6	32.5	31.5	42.2	35.2	30.9	28.3	34.1	34.8	32.4	33.4	34.8	34.9	42.7	31.7	35.0
	12:00:00	57.3	51	53.2		33.4		30		26.1	41.8	58.3	51	50.1	54	49.9	26	42.7	29.8	58.4	29.5	45.0	58.7	51	53.7	57	39.5	46.3	43.8	50.0
	18:30:00	46.3	43.5	42.2	36.7	30.3	35.4	32.2	30.3	27.9	38.1	46.1	37.4	37.4	36.6	40.4	31.7		32.6	37.5	31.7	36.8	44.1	41.6	43.9	44.1	38	54.5	35.7	43.1
	21:00:00										#DIV/0!											#DIV/0!								#DIV/0!
Wednesday, 23 January 2019	07:30:00	28.4	29.6	29.2		26		25.6		26.1	27.5	28.4	26.3	28.8	28.7	26.5	26.2	27.7	26.5		24.5	27.1	28.2	28.7	29	29.6	27	29.2	25.9	28.2
	12:45:00	41.1	40	41.2		32.9		32.3		32.8	36.7	40.5	34.4	38.9	40.2		36.3		34.1		36.1	37.2	41.8	39.1	40.6	41.9	34.6	37.1	36.6	38.8
	17:38:00	48.5	47.8	46.1		37		35.4		33.2	41.3	49.2	40.4	45.7	46.2	41.3	34		35.2	43.8	33.5	41.0	49.6	45	46.3	47.3	39.4	54.5	38.3	45.8
	9:42:00pm	30.4	29.9	29.7	27.9			26.7		26.8	28.6	28.4	24.2	29.2	28.5	26.6		26.7				27.3	29.4	29	29.9	29.8	26.7	24.1		28.2

Data Logger no. 6 - round concrete thing / Data Logger no. 7 - first tree pit / Data Logger no.8 - second last tree pit

Date	Time	6 concrete round thing	6 bitumen pathway	brick wall under butcher special sun	brick wall under butcher special shade	concrete pathway under special sun	concrete pathway under special shade	new concrete gutter	6 bitumen road	divided by no. of	7 grass tree pit - closest side to house: grass in sun	7 grass in shade	black tree pit sun	black tree pit shade	bark in garden	tree trunk	in front of tree pit - gutter	bitumen road	divided by no. of	8 grass tree pit - closest side to house: grass in sun	8 grass in shade	black tree pit sun	black tree pit shade	bark in garden	tree trunk	in front of tree pit - gutter	bitumen road	divided by no. of	Air Temperature	Conditions
Monday, 21 January 2019	07:50:00	27.5	28.7	26.6		27.3		26.9	30.2	27.9	26.9		28.1		26	26.2	29.2	30	27.7	25.9		26.9		24.7	25	28.6	30	26.9	26.2	overcast
	12:55:00	42.3	44.2	35.7		37.2		41.4	46.5	41.2	40.4		45.1		38.2	32.9	38.9	42.9	39.7	40.3		44		35.3	33.6	40.2	44.4	39.6	30.0	overcast
	17:30:00	30.4	30.7	28		28.3		29.3	32.4	29.9	27		28		26.3	25.7	30.5	32	28.3	26.3		27		26.3	25.8	30.2	31.3	27.8	29.6	""
	21:00:00	24.8	25.5	24.6		26.1		24.7	26.1	25.3	20.2		20.6		20.5	21.6	25.3	26	22.4	19.2		20.3		20.2	21.4	25.5	26.1	22.1	26.4	
Tuesday, 22 January 2019	07:50:00	31.4	33.9		28.4	30	29.4	28.6	32.8	30.6	34.4	29.9	33.8	28.3	35.6	31.6	29.8	31.9	31.9	33.3	28.6	33.6		31.9	34.3	29.9	32.2	32.0	27.0	Sunny
	12:00:00	56.1	51.4		35	48.6	30.7	48.6	59.3	47.1	65		74.6		70.2	37.7	45.9	56.6	58.3	65.5		77.2		65.5	37	49.9		59.0	38.3	
	18:30:00	44.7	44.3	36.2	34.9	41.3		40.4	46.9	41.2		32.4		37.6	32.1	34.6	40.4	41.1	36.4	32.8		38.5	36.3	32.7	32.7	43.1	44.4	37.2	37.2	
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Wednesday, 23 January 2019	07:30:00	27.5	28.6		25.6	27.2	25.7	25.8	28.5	27.0	26			25.6	26.9	24.7	28.2	28.7	26.7	29.7	28.8	27.1		28.8	30.8	30.3	31.1	29.5	26.4dc	cloudy
	12:45:00	39.2	40.4		33		33.3	36.6	41	37.3		38.4		42.8	40.8	33.3	38	38.6	38.7		38.4		42.6	39.2	34.2	38.5	41	39.0	31dc	cloudy
	17:38:00	46.8	45.7	42.6	37.3	38.7	35.7	41.2	47.9	42.0	41.2	35.5	49.1	36	44	38.9	41.9	45.4	41.5	44.3	34.4	49.8	38.7	46.8	39.5	44.5	46.8	43.1	32.2dc	sunny part cloud
	9:42:00pm	27.5	28.5	26.7		28.5		25.4	29.7	27.7	23.4		21.9		22.6	23.8	28.4	28.1	24.7	22.6		22.7		22.2	24.7	29.8	29.4	25.2		

DATE	Data Logger no.1 - pole 1										
Time	Green bench	shaded bitumen path	Bitumen path	concrete around pole	metal pole itself	concrete gutter	bitumen road	concrete		tiles on vinnies	
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DATE	Data Logger no. 2 - pole 2									
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DATE	Data Logger no. 3 - pole 3									
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DATE	Data Logger no. 4 - pole 4										
Time	bitumen path	metal pole	concrete gutter	bitumen road	post office tile on ground		post office brick on wall		brick around garden		
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DATE	Data Logger no. 5 - pole 5							
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DATE	Data Logger no. 6 - round concrete thing								
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DATE	Data Logger no.8 - second last tree pit										
Time	nd tree pit -closest side to ho		black tree pit		bark in garden	tree trunk	in front of tree pit - gutter	bitumen road		Air Temperature	Conditions
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DATE	Data Logger no.1 - pole 1										
Time	Green bench	shaded bitumen path	Bitumen path	concrete around pole	metal pole itself	concrete gutter	bitumen road	concrete		tiles on vinnies	
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DATE	Data Logger no. 4 - pole 4										
Time	bitumen path	metal pole	concrete gutter	bitumen road	post office tile on ground		post office brick on wall		brick around garden		
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Time	concrete round thing	bitumen pathway	k wall under butcher special		ete pathway under special		new concrete gutter	bitumen road	
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DATE	Data Logger no.8 - second last tree pit										
Time	nd tree pit -closest side to ho		black tree pit		bark in garden	tree trunk	in front of tree pit - gutter	bitumen road		Air Temperature	Conditions
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DATE	Data Logger no. 5 - pole 5							
Time	bitumen path	concrete driveway	concrete gutter	bitumen road	metal pole	side of metal bin		
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DATE	Data Logger no. 6 - round concrete thing								
Time	concrete round thing	bitumen pathway	k wall under butcher special		ete pathway under special		new concrete gutter	bitumen road	
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Time	nd tree pit -closest side to ho		black tree pit		bark in garden	tree trunk	in front of tree pit - gutter	bitumen road		Air Temperature	Conditions
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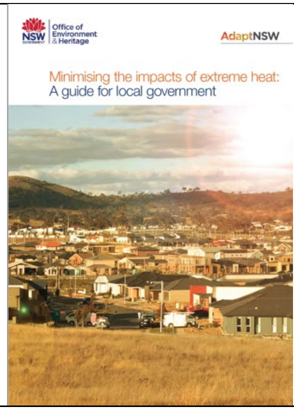
APPENDIX C: Literature Review

Preliminary Precedent Research on topics surrounding Urban Heat Island Effect, Urban Cooling and Urban Vegetation, with a focus on mitigation strategies utilised by small, rural and less-affluent LGA's.

Research Collated by UoN Students: Hannah Cheetham and Walter Rowlands

15. Minimizing the impacts of extreme heat. A guide for local government, 2016 NSW Office of Environment and Heritage + Adapt NSW	

What	A guide designed to describe ways NSW local governments can manage and minimise the impacts of extreme heat on the community, assets and services. The guide seeks to clarify roles and responsibilities in relation to extreme heat events and will examine ways in which local government can minimise the impacts of such events by adapting existing systems, procedures and activities.
Findings	1. “Extreme heat is defined as significantly hotter and/or more human than average summertime temperature for a location, whereby human and animal health, and the performance of infrastructure and trhe delivery of services may be adversely affected. This includes, but is not confined to heatwave conditions.” (NSW Government, 2016, P 4) 2. “The Bureau of Meteorology has developed a nationally consist approach to measuring and predicting heat events, which forecasts the location of heatwaves for the past two days and the next seven days.” (NSW Government, 2016, P 4) 3. “Extreme heat kills more Australians than any other natural disaster, and also impacts health and wellbeing. It can cause havoc to transport, utilities and other services, and causes significant losses in labour productivity, and costs to the Australian economy.” (Coates et al 2014) 4. “The NSW and ACT Climate Model (NARCLiM) shows, with high confidence, that NSW will experience more extreme heat in the future as a result of climate change. Hot days are expected to increase across the state by an average of 26 days per year by 2070… An overall increase in temperature means that current extreme heat events will become hotter, more frequent with increased duration and therefore more severe. Based on projections of increasing temperatures, it has been estimated that annual net temperature-related deaths (taking into account fewer deaths in warmer winters and more deaths in hotter summers) will increase by 1250 deaths in 2070, and 8628 deaths in 2100, nationally.” (Bi et al. 2011) (NSW Government, 2016, P 5) 5. Roles and responsibilities of the NSW State Heatwave Sub Plan, namely to: - distribute warnings and other relevant advice to local stakeholders - develop and implement strategies to minimise heat stress and the effects of heatwaves on vulnerable populations

	- assist as requested by the State Emergency Operations Controller (SEOCON) or Regional Emergency Operations Controller (REOCON) - provide regular information/ situation reports to REOCON (NSW Government, 2016, P 7) 6. The following online resources may be of interest when considering the development of strategies and arrangement for dealing with extreme heat: - Heatwave Planning Guide: Development of heatwave plans in local councils in Victoria. - Hunter Counsils' Heatwave Planning template for Lake Macquarie and the Central Coast. 7. "Extreme heat events have killed more Australians in the past 200 years than any other climate hazard (Coates 1996) 8. "During extremely hot weather, people can become dehydrated (loss of too much water from the body) or overheat, which can result in heat cramps, heat exhaustion or heatstroke." 9. "Some medications can become less effective or occasionally more toxic when stored in the ehat, and some medications can make people more susceptible to the effects of heat." (NSW Government, 2016, P 8) 10. " High temperatures have been linked to an increase in aggressive crimes in hot weather, such as civil unreast (Rotten and Cohn 2000A, 2000b), high levels of street violence, attacks and homicide (BOM n.d), road rage (Kenrick and MacFarlane 1986), and domestic violence (Auliciems & Bartolo 1995). 11. There are environmental health risks caused by extreme heat events: 11.1 Water Quality: Surface water can be impacted by extreme heat events through outbreaks of algal blooms as well as being contaminated from runoff from bushfires. 11.2 Air Quality: Extreme heat events may exacerbate air quality issues, such as pollution from bushfires, car exhausts and industrial fumes and well as increased levels of ozone. The lack of breeze or wind can allow pollution to stagnate, causing air quality health impacts, and prolonged dry conditions can increase rates of dust and pollen, and also result in bushfires. Extreme heat events also increase the use of air conditioning and private transport which results in greater air pollution. 11.3 Food Safety: Higher air temperatures can increase cases of salmonella and other bacteria-related food poisoning because bacteria grow more rapidly in warm environments. Food safety can also become an issue if black-outs cause refrigeration to be interrupted. (NSW Government, 2016, P 9) 12. Service Impacts: Extreme heat can disrupt electricity supply networks, causing economic impacts, while also impeding the ability of individuals to manage their exposure to high temperatures.
Proposed Strategies	1. Green cover: 1.1. Cool roofs and walls. Roofs that are partially or full vegetated (green roofs) or roofs that use reflective materials to reflect and emit solar energy (cool roofs), can decrease heat absorption, thereby reducing ambient air temperature and minimising heat impact. Green walls are vegetated systems on a vertical façade, and have been shown to reduce adjacent pavement temperatures by 5°C. 1.2. Cool pavements, streets and carparks, using reflective and/or permeable materials for roads, carparks and footpaths can reduce the amount of hard, paved and dark coloured surfaces that cause UHI. 1.3. Green open spaces; increasing the number of canopy trees, to provide shade to grass areas, cycleways, parklands and

	amenities can reduce the amount of heat absorbed and radiated by open spaces. 1.4 Planting urban forests. 1.5 Urban designs that redirect wind, control humidity and water and consider thermal qualities of materials can also minimise temperatures. Even if not applied on a broad scale, small scale heat refuges at street level can improve community amenity and functionality. Geothermal cooling (where wind is tunnelled underground and cooled by the earth) and misting are two tools that can actively reinforce cool space within cities. (NSW Government, 2016, P 11) 2. Work Health and Safety Under section 19 of the Work Health and Safety Act 2011, an employer has a legal duty to ensure health, safety and welfare at work of all employees. 3. Event and recreational policies: Sport Medicine Australia (SMA) has released Hot Weather Guidelines for sporting clubs and associations and the physically active, which explore when it is safe to play sport or to be physically active in the heat. It canvases issues such as altering playing periods, training times or venues and scheduling events outside the hottest part of the day, usually 11am-5pm. 4. Asset Management: Some asset management considerations that may emerge due to extreme heat events include: - the repair and maintenance of road infrastructure (which may fail depending on the thermal performance of construction materials). - power outages that impact on workforce productivity and availability of public facilities. - infrastructure that is not designed to cope with extreme heat, including road and bridge surfaces, IT transmission stations, sewerage and water pumping stations, community buildings that rely on passive cooling etc. - Council owned or supported food businesses or health services. - Additional maintenance required of cool spaces due to increased patronage such as swimming pools. - Staff absenteeism due to carer responsibilities or inability to travel to work – particularly in peri-urban areas where bushfire response responsibilities may take precedence. (NSW Government, 2016, P 14) 5. Communicating with local stakeholders: Responding effectively to extreme heat requires individuals, families and communities to understand and address the impacts of extreme heat as individuals, and also to recognise and care for those most at risk in the community. There is less public awareness of the impact of extreme heat on health, compared to other extreme weather events. (NSW Government, 2016, P 15) 6. Beat the Heat is an educational campaign aimed at improving individual understanding about how to avoid heat-related illness. (NSW Health 2015). Key messages of the NSW Beat the Heat campaign: - Drink plenty of water - Minimise physical activity - Check on elderly friends, neighbours and relatives, especially if they live alone. - If you have an air-conditioner, make sure it is working before you need it. - If you don't have air-conditioning, spend time in a cool place like a library, shopping centre or cinema. Try to go early, so you're not outside in the middle of the day. - Plan your day around the heat – avoid being outdoors between 11am and 5pm. - Avoid alcolock, hot or sugary drinks. - Take cool showers or baths.

	- Wear light coloured, loose fitting clothes made from natural fibres like cotton. - Cool your house by shading windows, shutting curtains and, if it's safe to do so, opening windows at night to let in cool air. (NSW Government, 2016, P 17)
References	1. AdaptNSW, Climate Projections for NSW, Office of Environment and Heritage, Sydney. 2. Auliciems, A and Di Bartolo, L 1995, 'Domestic violence in a subtropical environment: police calls and weather in Brisbane', International Journal of Biometeorology, 39: 34–39. 3. Australian Attorney-General's Department, Heatwave visual guide, Disaster Resilient Australia, Australian Emergency Management Institute. 4. Bi, P, Williams, S, Loughnan, M, Lloyd, G, Hansen, A, Kjellstrom, T, Dear, K and Saniotis, A 2011, 'The Effects of Extreme Heat on Human Mortality and Morbidity in Australia: Implications for Public Health', Asia Pac J Public Health 1010539510391644, doi:10.1177/1010539510391644. 5. Bureau of Meteorology, Pilot Heatwave Forecast 6. Bureau of Meteorology, Heatwave Service for Australia 7. Coates, L 1996, 'An overview of fatalities from some natural hazards in Australia', in RL Heathcote, C Cuttler, J Koetz (eds), Proceedings, NDR'96: Conference on Natural Disaster Reduction, Institution of Engineers Australia, 29 September – 2 October 1996, Surfers Paradise, Queensland, pp. 49–54. 8. Environmental Health Standing Committee (enHealth) 2012, Risky business – a resource to help local governments manage environmental health risks, Australian Health Protection Principal Committee, Canberra. While this document is specific to environmental health risks, it provides a useful framework that could be used for assessing other risks for LG 9. HCCREMS 2014, Heatwave Planning template for Lake Macquarie and the Central Coast, Hunter and Central Coast Regional Environmental Management Strategy. 10. Kenrick, DT and MacFarlane, SW 1986, 'Ambient temperature and horn-honking: A field study of the heat/aggression relationship', Environment and Behaviour, 18(2):179–191. 11. NCCARF 2013, Policy Guidance Brief 9: Managing heatwave impacts under climate change, National Climate Change Adaptation Research Facility, Southport QLD. 12. NSW Department of Education, Supporting students during hot weather. 13. NSW Health 2015, Beat the Heat, Department of Health NSW, North Sydney, accessed November 2011, www.health.nsw.gov.au/environment/beattheheat/ pages/default.aspx. 14. NSW Health 2009, Disaster Risk Management Guidelines, Department of Health NSW, North Sydney. 15. NSW Office of Water 2013, NSW Guidelines on assuring future urban water security: Assessment and adaption guidelines for NSW local water utilities, NSW Office of Water, Parramatta. 16. OEH 2015, Technical Guidelines for Urban Green Cover in NSW, NSW Office of Environment and Heritage, Sydney. 17. Price Waterhouse Coopers 2011, Protecting human health and safety during severe and extreme heat events: A national framework, report to the Commonwealth Government, Australia. 18. Queensland University of Technology 2010, Impacts and adaptation response of infrastructure and communities to heatwaves: the southern Australian experience of 2009, report for the National Climate Change Adaptation Research Facility, Gold Coast, Australia. 19. Rotton, J and Cohn, EG 2000a, 'Violence is a curvilinear function of temperature in Dallas: A replication', Journal of Personality and Social Psychology, 78(6):1074–1081. 20. Rotton, J and Cohn, EG 2000b, 'Weather, disorderly conduct and assaults: From social contact to social avoidance', Environment and Behaviour, 32(5):651–673.

21. Sports Medicine Australia, Hot weather guidelines for sporting clubs and associations and the physically active.
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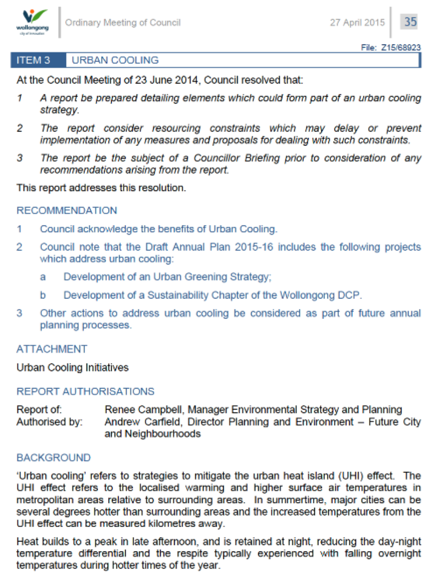
23. Victorian Department of Health and Human Services 2012, Heatwave Planning Guide: Development of heatwave plans in local councils in Victoria.
24. Victorian Department of Health and Human Services 2014, Evaluation of Victorian Stratsegies.
25. Zander, K, Botzen, WJW, Oppermann, E, Kjellstrom, T and Garnett, ST 2015, 'Heat stress causes substantial labour productivity loss in Australia', Nature Climate Change, 5(7).

17. Urban Cooling Initiatives

Preliminary Report 2015

Wollongong City Council



Ordinary Meeting of Council 27 April 2015 35

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ITEM 3 URBAN COOLING

At the Council Meeting of 23 June 2014, Council resolved that:

1 *A report be prepared detailing elements which could form part of an urban cooling strategy.*

2 *The report consider resourcing constraints which may delay or prevent implementation of any measures and proposals for dealing with such constraints.*

3 *The report be the subject of a Councillor Briefing prior to consideration of any recommendations arising from the report.*

This report addresses this resolution.

RECOMMENDATION

1 Council acknowledge the benefits of Urban Cooling.

2 Council note that the Draft Annual Plan 2015-16 includes the following projects which address urban cooling:

a Development of an Urban Greening Strategy;

b Development of a Sustainability Chapter of the Wollongong DCP.

3 Other actions to address urban cooling be considered as part of future annual planning processes.

ATTACHMENT

Urban Cooling Initiatives

REPORT AUTHORISATIONS

Report of: Renee Campbell, Manager Environmental Strategy and Planning

Authorised by: Andrew Carfield, Director Planning and Environment – Future City and Neighbourhoods

BACKGROUND

'Urban cooling' refers to strategies to mitigate the urban heat island (UHI) effect. The UHI effect refers to the localised warming and higher surface air temperatures in metropolitan areas relative to surrounding areas. In summertime, major cities can be several degrees hotter than surrounding areas and the increased temperatures from the UHI effect can be measured kilometres away.

Heat builds to a peak in late afternoon, and is retained at night, reducing the day-night temperature differential and the respite typically experienced with falling overnight temperatures during hotter times of the year.

What	Meeting notes and recommendations for the development of an Urban Cooling Strategy.
Findings	3.3 Built form: city structure Building density, wind flow, surface area exposed to solar radiation, orientation, and composition influence the ability of heat captured by structures to be released into the atmosphere. Improved urban design for environmental performance and human comfort helps to mitigate the UHI effect. 3.4 Human activity

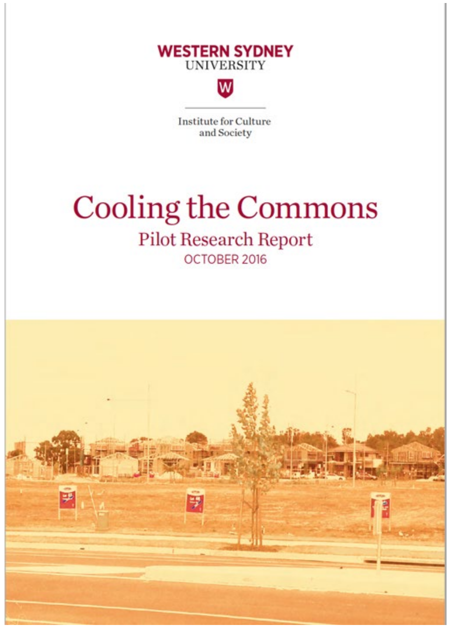
	The overall population, and the way people interact with the urban environment, creates pollutants, waste heat and waste gases, through the use of motorized transport, body heat and respiration, air conditioning, and energy consumption. Reducing the demand for energy and a reduction in waste gases helps to mitigate the UHI effect." (Wollongong, 2015, P 3) 4. "Climate change is predicted to increase minimum and maximum daily temperatures by 1.5-3.0°C in Wollongong by 2050." (Wollongong, 2015, P 3) 5. "Extreme temperature events (three consecutive days of 29 degrees Celsius or more) will increase over time in frequency and severity in Wollongong" (Wollongong, 2015, P 3) 6. "Due to Wollongong's coastal location, the UHI effect in the CBD is to some extent mitigated by favorable sea breezes" (Wollongong, 2015, P 3) 7. "Cooling the urban environment can be achieved through a combination of quality urban design, the use of high-performing materials, increased and diversified urban vegetation, and a reduction in localized emissions from transport and energy use. These principles are closely aligned with the Community Objectives and Goals in the Wollongong 2022 Community Strategic Plan (CSP)." (Wollongong, 2015, P 3) 8. Council have formulated a series of over-arching actions which, when implemented with physical UHIE mitigation strategies, will result in a more successful approach to negating the effects of the UHIE. These over-arching actions include: - "Coordinate Council's Environmental Programs - Coordinate natural area restoration works at priority sites - Coordinate community environmental programs - Implement behaviour change projects which align with Council's Environmental Sustainability Policy and Strategy - Implement and review annual water and energy savings actions - Implement resourced actions from the Environmental Sustainability Strategy - Engage with other tiers of government and the development/building industry to achieve improved development outcomes - Train key staff in green building/development principles - Commence implementation of the revised Wollongong Bicycle Plan when adopted - Assess the feasibility to expand the Gong Shuttle service to outer suburbs - Implement footpath and cycleway improvement programs and the development of city wide pedestrian plan - Accelerate capital program for footpath renewal." (Wollongong, 2015, P 4) 9. Risk factors associated with the UHIE have been identified by WCC. These risks include: 9.01 Air Quality: Higher temperatures result in poorer air quality, rate of chemical

	reactions of common pollutants increases therefore increasing formation of smog, ground level ozone, other pollution 9.02 Public health Increase in heat stress-related mortality and illness, heat exhaustion/heat stroke, aggravated respiratory problems, higher risk for the vulnerable 9.03 Higher energy use Increase in GHG emissions, increases in electricity demand for air conditioning and lighting 9.04 Power shortages Peak energy use spikes, network failure and overload 9.05 Economic impacts Lower real estate values, reduced consumer spending, lower attendance and adverse impacts for patrons at public events 9.06 Behavioural Increase in level of violent assault, domestic violence, crime and antisocial behavior 9.07 Water demand Increased demand for hydration, cooling, irrigation 9.08 Wellbeing Reduced comfort and amenity, decrease in quality of urban space and experience impacts on wellbeing 9.09 Transport Buckled train lines, failure of air conditioning systems, electrical faults, delays, motor vehicle breakdowns, soft sticky deteriorating roads 9.10 Flora and Fauna Vegetation and animal stress and mortality, increased rate of evaporation
Proposed Strategies	Refer to page 8 and 9 (Information is clearly and concisely presented in table formats.
References	Nil.

18. Cooling the Commons

Pilot Research Report October 2018

Mapping Urban Resilience in Riverland Sydney (MURRS) - Western Sydney University - Institute for Culture and Society



What	“The report provides initial insights into how residents living in Western Sydney keep cool during the hottest parts of the year and how they would like to see their living environments, at home and out and about, modified to improve wellbeing in a climate changing world. The research responds to a lack of qualitive information about: day to day living practices in outer suburban Sydney; the constraints people experience when trying to keep cool; and, people’s aspirations for more comfortable living environments. (MUURS, 2018. P. 3) The study reviewed factors that combine to produce urban heating in Sydney’s rapidly developing urban fringe and the key socio-environmental issues that researchers have identified as important. These include the health effects of periods of extreme heat and research highlighted the dearth of information about how residents move around in space and interact with the physical environment and in turn how the changing build environment of the urban fringe is shaping new forms of individual and social behaviour. The concept of the ‘cool commons’ was employed to identify those spaces that offer cooler temperatures than surrounding areas and that are used by, and are accessible to, a community of commoners who to some degree, care for, take responsibility for, and benefit from this coolness. The working hypothesis is that if effective and environmentally resilient ways that communities are already keeping cool are identified, urban design and public policy might be better placed to support this grassroots adaptation and experimentation.”

	(MUURS, 2018. P. 3)
Findings	"The report finds that older people employ a range of creative practices in their largely un-airconditioned homes to cool down, while younger people and those with disabilities resort to curtailing their physical activity. There is a high degree of appreciation of the residual cool commons, that is, those cool spaces that are a legacy of past actions of tree planting or restrictions on river shore occupation, or of past skills and practices of cooling that may or may not have been maintained." (MUURS, 2018. P. 3) "A further finding is that people are drawn to the transgressive cool commons that have been produced by acts that are illegal or not condoned, such as occupying 'private' air-conditioned spaces for extended periods of time (in shopping centres, McDonalds or community centres) or use of water features for play." (MUURS, 2018. P. 3) "The most important finding is that there is a strong aspirational cool commons, that is, what people would like to see as constituting a cool commons in their environments. In the data, aspiration commons were linked to the provision of basic cooling amenities (shade, shelter, water) coupled with the provision of paths and walkways. They were also linked to improved access to water play, parks and pools." (MUURS, 2018. P. 4) "The findings show that shade, shelter and water commons are desired for a cool future city. Built and social interventions are needed to promote urban green space and encourage its use. However it is not a case of "build it and they will come" or "regulate and they will behave." Normative social practice's that have grown up around current conditions, such as children playing indoors for large parts of the day, will be difficult to budge, and require action in relation to both the built and social environment on an ongoing basis." (MUURS, 2018. P. 4) "Western Sydney is facing specific climate change challenges including water scarcity, soil degradation and urban heat island effect resulting from the replacement of vegetation with heat-absorbent surfaces. Western Sydney is not reached by the cooling sea breezes associated with coastal cities, and can be 10 degrees hotter than the Sydney's harbourside Central Business District (WSROC 2008; Hopkins & Goodwin 2011; Jacobs nd); a situation that is likely to grow worse in the future due to the differential impacts of climate change (WSROC 2008; DIICCSRTE 2013; Brown 2012)." (MUURS, 2018. P. 8) "Western Sydney has the highest proportion of grass-bare ground in NSW, with Blacktown, Camden, Fairfield, Liverpool and Penrith all boasting significant areas of potentially plantable space (Jacobs et al 2014a, p.26)." "Whilst grass-bare ground can be considered a form of 'urban green space' and is better than hard concrete surfaces in terms of managing ground temperature and storm water, and reducing the build up of urban heat (Jacobs et al 2014, p.39), it does little on its own to increase the amenity of open public environments. (Sofoulis et al 2008, p.40). People require shade of various sorts as well as other basic amenities such as water fountains, seating and toilets in order to use and move through open spaces comfortably and, importantly, to perceive these spaces as useable and 'liveable' (Sofoulis et al 2008)." (MUURS, 2018. P. 9)

	"Green space is linked to public health and well-being where upgraded and visibly maintained parks are perceived to be safer and more likely to be visited (Hunter et al 2015, p. 251-2)." (MUURS, 2018. P. 9) "A lack of public transport infrastructure, including bus shelters, linking people to parks, shops, and facilities such as swimming pools, is another challenge inhibiting the ability of people to get about comfortably in Western Sydney." (MUURS, 2018. P. 9) "Penrith has experienced significant loss of trees where new housing developments have occurred. Apart from clearing the sites to achieve economic feasibility, development guidelines include reduced street widths and block sizes. As a result, new developments have narrow easements for only small street trees, significantly reduced areas for residential gardening, and nearly continuous roofs." (MUURS, 2018. P. 10) " A study of emergency hospital admissions in five regions in NSW – Sydney East and West, Illawarra, Gosford-Wyong and Newcastle, showed that on extremely hot days there was an increase in heat related injuries such as dehydration. Those with existing conditions such as cardiac and respiratory diseases, and mental health problems, are more susceptible to heat related injury and death (Khalaj et al. 2010)… Workers at risk from exposure to extreme heat include those who work outdoors, such as construction workers and builders; maintenance workers; farmers and emergency and essential service providers (Hanna et al, 2011)." (From the Climate Commission's 'The Critical Decade: New South Wales Climate Impacts and Opportunities (Steffen & Hughes 2012, p.10). (MUURS, 2018. P. 12) "There is a direct correlation in the research between greener neighbourhoods, lower 'sitting time,' and the likelihood and frequency of moderate physical activity such as walking, which has known health benefits (Astell-But et al 2014)." (MUURS, 2018. P. 12) "Drawing in Gibson-Graham et al (2013) we use the term 'commons' to refer to that which is made, cared for, and shared by a community, including biophysical resources, material infrastructures, socio-cultural practices, and knowledges." (MUURS, 2018. P. 13) "The i-Tree assessment study positions itself as part of "a process to catalyse social change in Australia's urban areas" and indicated the need for a strategic approach to improving tree cover to manage urban heat (Jacobs et al 2014, P.37). Other studies detail design strategies to mitigation increasing urban temperature, for example, the Green cover Demonstration Project Liverpool City Centre and Penrith (2011) prepared by the NSE Government Architect's Office, which underscores the importance of the designed environment to enhance community resilience and the capacity of local government to respond to the heat effects of climate change. However, these top down design strategies will only be successful if there is grass roots involvement by concerned citizens and buy-in from powerful institutional actors such as urban developers." (MUURS, 2018. P. 14) " In the discussions with Penrith City Council preceding the report staff reported public antipathy towards trees due to issues such as mess

	and potential danger." (MUURS, 2018. P. 14) "The key findings from the interview data are presented for each group and according to the relevance of four emerging themes: 1. What participants did at home to keep cool (strategies at home); 2. The perceived and experienced amenity of public environments; 3. Tree stories and; 4. Perceptions of what a cool future city should or could be. 1. Group 1 (Penrith Seniors) "This group of 14 women aged 55+ from Kingswood and St Marys were keenly aware of the costs of keeping cool. They practiced a variety of cooling strategies around the home and had effective ways of micromanaging their energy use. Four of the participants in Group 1 kept private pools. They conveyed a strong perception of not being listened to or being left out of decision making processes affecting their city. 1.1 Strategies at home: Water, air conditioning, refrigeration, curtains, canvas awnings, sprinklers, doors, baths, blinds, shutters, sheets, towels and facecloths are essential resources for keeping cool at home. Wetting and draping material, or freezing water in cake tins and blowing cold air over them as cooling strategies. Wetting wrists and ankles and wearing wet wristbands – why there is a need for public bubblers. Perceived the use of potable water in toilets as a waste. Many of the cooling strategies practiced by this group were to accommodate poorly oriented housing, as one participant joked "you can't change your house around." The majority had sliding rather than sash windows, which doesn't allow for the top part to be opened to allow hot can to escape. Many older housing commission houses have tin roofs and may lack insulation. Keeping their homes closed up and dark, drawn curtains and closed doors. Covering West facing windows with paper. Using ceiling fans and opening windows at night. Participants commented on a generational change – that their children all had air conditioning and were 'less tolerant' to heat than they were. They also commented about a general loss of skills in the younger generation, with young adults not knowing how to fix a leaky tap or change a fuse. There was a great respect for air conditioning, but it was treated as a finite resource.

	They had clear opinions about the design of new housing; and had noted the use of dark bricks and Colorbond roofing a lack of eaves, small gutters and downpipes and lack of space between houses for drafts to circulate. Participants in this groups felt too old to benefit from investing in solar panels and lithium batteries because it could take 20 years to get the saving benefit. Many spoke of the benefits of roof ventilators (whirly birds) which were seen as effective at drawing out hot air. 1.2 The Amenity of Public Environments: Participants enjoyed going to air-conditioned clubs; some talked about sitting in the river when they were younger and walking along 'mulberry tree walk' at Tench reserve. Where possible some "escaped" to the mountains. There was a real sense of resentment about the lack of public amenities such as seating, shade, water and toilets, with many comments about bubblers, trees and seating being removed from pubic areas in Penrith and not replaced. Removal and replacement of mature Plane trees was discouraged, as 20 years of growth would be lost and they would not live to feel the benefit of the new trees once matured. Removal of older pavement (terracotta toles) and replacement with grey tiles were said to make the area hotter, slippery in the rain and not wearing well. "You have to go to the shopping box to keep cool," explained one participant. Comments were made about how sufficient seating for the elderly have been removed as shopping centres want to disincentivise loitering. This forces people tp sit in coffee shops to take breaks and thus spend more money. Lack of access to free, clean and cool water was a keenly felt problem. At Penrith Station "you have to go into the toilet to get a drink" Service providers such as the Post Office, MyGov and Centrelink are too far apart from one another, making access difficult. Participants felt that bus stops did not protect them from the rain nor the sun. 1.3 Tree Stories There was a general agreement for the need to plant street trees for shade, cooling and weather protection, particularly at bus stops. The group had strong opinions about the appearance and 'appropriateness' of trees, with quite strict qualifications as to what constitutes an acceptable, or 'worthy' tree.

	There was a general dislike and distrust of Eucalyptus due to falling branches. Eucalypts were perceived as a particular threat when in close proximity to a house (insurance companies are now explicit about framing trees in close proximity to houses as a liability). 'Appropriarte,' 'sensible' trees suggested in Group 1 were: Jacaranda, Tibouchina, Crepe Myrtle, Bottle Brush (for birds), Olive Trees, deciduous trees (as you only need to rake up the leaves once a year), Magnolia Soulangea and grape vines. Concern was expressed about trees in bushfire zones and also water scarcity both in relation to the heat and population. 1.4 Cool Future City: There is a need for a cool central park in Penrith with avenues of trees going out lined with shops, lots of green space, green roofs; water fountains and (movable) sails over walkways. Misting machines (are better as you are not walking over roots etc) Narrower walkways, with vines growing up for shade (Like South Bank in Brisbane), and multi-use of spaces such as car parks. Car parks could be made from grass-crete to reduce heat and glare and could be used for other activities. Increase cool and permeable pavement. Trees every 5-6 cars in all car parks. " (MUURS, 2018. P. 18 - 24) 2. Group 2 – Carers at NADO "A chief concern for this group of 7 women and 3 men from Kingswood and St Marys, all ages 55+ and all carers of children with disabilities aged 21-61 years, was how to achieve a good quality of life with reduced mobility. Coping with the heat was extremely difficult out and about, and so many of the participants in group 2 spent the vast majority of their time indoors, in their own homes, or at the NADO centre. 2.1 Strategies at home: All participants had air conditioning at home. Peak afternoon heat was a problem and dealt with by keeping windows, thermal curtains and shutters closed. Private gardens were important to many carers, with one participant trying to 'save' his garden by putting in water tanks. Comments were made in the change in climate in Australia – going from four seasons to two – Winter and Summer.

	Participants generally disliked the new housing developemnts with their small back yards such as Urban Growth's compact development 'Thornton' near Penrith Station, and the treeless housing in Jordon Springs. 2.2 The Amenity of Public Environemnts: Moving about the city in hot weather, even in a car, was generally perceived as uncomfortable. The lack of shade, and pedestrian lights not lasting long enough for them to comfortably get across a road comfortably with a wheelchair are problems for this group. The participants experienced considerable challenges transporting their children to and from the NADO centre. When it is very hot in the car, disabled people can have seizures; so on very hot days they must stay at home, which has social consequences. The Central Gardens in Merrylands are enjoyed of a morning (but not in the afternoons as commuting to and from gets too hot). There was a dislike for parks that were 'too open' with treeless playing fields. The radient heat from car parks and roads were seen as a deterrent to visiting this park. Lack of seating under shade at the off-leash section of the dog parks, so dog owners stand out in the blazing sun. Often shady parks are not the accessible parks, accessible parks (often being modern, don't have mature trees or shading so un-usable in hotter weather. The mountains were seen as a cool 'retreat.' 2.3 Tree Stories: A participant is Group 2 described Eucalypts, Planes and deciduous trees as 'dirty.' A preference was expressed for native trees and there was a concern about natives in the Cumberland Plains being affected by disease and dying. Pines were perceived as having root problems. Participants in this group described Jacarandas, Crepe Myrtle, Gordonia and Bottle Brush as 'trees that are worthy,' 'safe for public,' and 'environmentally friendly.' The aesthetic dissonance produced by pruning to make way for electricity wires disturbed group 2 participants. Wheel chairs and walking frames do not cope well with lead little, flower fruit falls or tree roots.

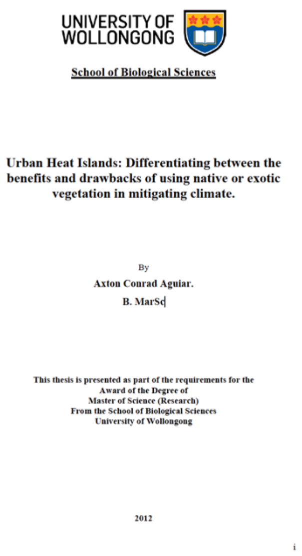
	2.4 Cool Future City: Nightly street cleaning so that wheel chairs don't slide on leaf litter. More community events to be held by Penrith Tiver. Better planning and limit cul-de-sacs that serparates neighbourhoods, inhibit walking, and increase travel times. Like street scapes with back lanes for accessing garages, with trees and no parking out in the street." (MUURS, 2018. P. 24- 28) 3. Group 3 – Aboriginal Supported Playgroup "The ten Aboriginal and /or Torres Strait Islander women in this group all had small children less than 5 years of age. In summer, people need to move downstairs in their homes and that they spend a lot of time in the neighbourhood centre, which is air conditioned. 3.1 Strategies at home: None of the participants in Group 3 had air conditioning or other forms of artificial cooling in their homes. Typically the community lives in rented housing that is porrly designed and in fire need of maintenance. This community is isolated and experienced a number of social problems that were exacerbated by the nature of the built environment. Group 3 expressed less capacity than the previous groups to modify their environments and maximise cooling. A coping strategy in Group 3 was to remain as still as possible, with one participant saying that she lies on the bathroom floor. The social pull of the playgroup was enough for people to overcome their inertia, supported by the air conditioned bus from the Centre that transports parents, carers and children. 3.2 The Amenity of Public Environments: Mothers in Group 3 had memories of riding bikes and scooters around the streets, but said that their kids don't ride as it is too hot. Kids didn't play after school but came home "just to chill." Streets are too hot for parents to push prams or walk.

	Children at Penrith and Blacktown child cares can only play outside until 10am – when it gets too hot, whereas children in the Mountains can play outside all day. There are no parks shady enough in the area for the council sponsored mobile play van to visit. Participants with cars took children to shopping malls or to McDonalds to stay cool. Older children go to Blacktown outdoor pool. Nurragingy Reserve Water Park is good for play to keep cool but hard to access if you don't own a car. One participant said that she can not take her children to the local pool to stay cool as it's too hot, the equipment gets too hot to play on and there is a lack of shade cloth. 3.3 Tree Stories: The same distaste for large Eucalypts was prevalent, with Tibouchina pointed out as a preferred tree. Trees seemed to be a long way from the key concerns of this group, and the relation between their wellbeing and trees was not clearly perceived. 3.4 Cool Future City: Ideas focussed on the health and wellbeing of the children, and there was a strong relation between water and play. The need for kids to safely socialise was important, with a desire for "little lakes, little water parks" and places they could ride bikes. Lack of accessibility is a problem." (MUURS, 2018. P. 28 - 30) 4. Strategies employed by Community Centres: "During site visits interesting cooling strategies and signs of heat stress related to the accessibility of water. Water was fundamental to play for the teenagers of Cranbrook and the 'fun cooling' witnessed at Koala Childcare Centre, where workers sprayed fully clothed children with a hose. Water scarcity challenges the capacity to create a cool environment through planting….A well irrigated environment was understood in this context as a caring and cared for environment." (MUURS, 2018. P. 31)

	5. Issues Undermining the Capacity for Active Commoning: " The compromised liveability in our hotspots can be linked to a few key structural issues that leave environments vulnerable to heat stress and undermine community capacity for commoning. These are: - Lack of amenity (shaded seating, water fountains, and toilets) to facilitate moving around in public spaces. - Lack of cooling shade for areas of waiting (such as bus stops, traffic lights, sports fields), playing (shade cloth for play equipment in parks), and walking. Places to go to rest in shade, get a drink and go to the toilet are important, regardless of whether these are 'public' or 'private' environments. - Lack of trees. Street trees are needed, particularly around bus stops; however, there was a perception that the opposite is happening and street trees are being removed. Not all trees are seen as equal, with some deemed more appropriate than others. Large Eucalypts in parks or near homes were considered particularly threatening, and there was a relation between the pruned, maintained tree and the acceptability of the tree species. Recent events such as storms and bushfires have negatively impacted on the perception of trees across all groups. - Lack of access to free, clean public water for drinking and for play was a keenly felt problem across the groups. Participants expressed concerns about water scarcity both in relation to the heat and growing population. - Dislike of new housing developments and a sense these are not designed to facilitate cooling. Groups did not see these developments as part of the existing community. - There was a feeling of not being listened to by decision makers in relation to the design of the city. Participants felt that they have creative ideas they could contribute." (MUURS, 2018. P. 33)
Proposed Strategies	1. "People said they would like to see an increase in events help in cool commons and the multiuse of existing purpose-built environments at alternative times of the day (such as car parks). Evenings and nights were identified as more comfortable times to inhabit cool commons. Aspirational commons could include the reactivation or rekindling of common knowledge that people exercise in their private homes (for example cooling home modifications, repair, gardening or practice such as bike riding for example). We see in these aspirations potential to develop interventions to engage the community in cooling the commons. " (MUURS, 2018. P. 32) 2. Recommendations for Further Research:

		“ Our findings show that shade, shelter, and water commons are required for a cool future city. However, it is not a case of ‘build it and they will come’ or ‘regulate it and they will behave.’ Normative social practices that have grown up around current conditions, such as children playing indoors for large parts of the day, will be difficult to change, and require action in relation to both the built and social environment on an ongoing basis. The listlessness of participants in Group 3 for example, is not a matter of choice; it is a result of a range of social and material conditions constraining the ability of people to move about their environment comfortably. As people grow more sedentary, they also grow less git and able to cope with physical activity. Social adaptations that have occurred in response to the heat nonetheless demonstrate the ‘improvisory potential’ of people (Pink & Leder-Mackley 2015) and it may be that adaptive strategies will eventually need to be quite dramatic.” (MUURS, 2018. P. 34) “ The research reviewed indicated the importance of (built and social) interventions in encouraging usage of urban green space and activating commoning. It is critical for the communities directly affected to be involved in the design of such interventions. 2.1 A Co-Design Approach: There is the potential of taking a co-design approach to further research. Co-design, a standard of practice in design-led community consultation, would help us to determine what sorts of commoning practices people are interest in investing their time and energy in and what they need in order to pursue this. Co-design as a mode of research gathers social data through workshops that elicit the creativity of participants in ideation processes, developing prototypes for physical infrastructure and amenities or for new social enterprises. This can involve ‘fun exercise’ such as creative mapping that allow for emotional layering on geographical places – how they are lived and experienced now, and how they might be lived and experienced in the future.” (MUURS, 2018. P. 34) 2.2 Access to Cool Commons: “ A review of international initiatives and approaches reveals many possibilities that we could try here, including a service approach to the built environment. For example in Pittburgh in the US, when ‘real feel’ temperatures reach (equivalent) 32°C ‘cooling retreats’ are opened across the city for residents aged 60 years or older, with refreshments served. More research is needed to explore the potential for cooling refuges and how the community could access these.” (MUURS, 2018. P. 35) 2.3 Water Commons: “Water had a material, social and symbolic value in the creation of cool commons…More public access to water in parks and other public environments is required but in a way that demonstrates sensitivity to issues of water scarcity. It is recommended therefore, to explore opportunities for greater access to public water; to expand the possibilities for events located in river-side locations and to improve accessibility to those events.” (MUURS, 2018. P. 35)

	2.4 Understanding Trees: “More work needs to be done to facilitate a change in attitude toward trees. This could be achieved by engaging community to select feasible trees that they also see as being appropriate, as well as enabling community to share their knowledge about trees with others.” (MUURS, 2018. P. 36) 2.5 Cooling Practices: “The Penrith Cooling the City Strategy stresses the importance of encouraging cooling on private property, as it covers so much land (2015, p.17). This method of research could facilitate the sharing of personal cooling strategies and in contrast to the focus on private property, hoe they might translate into forms of commoning beyond the individual home. Inviting people to photograph and take the temperature of their home environments and record these in a diary form or enter their data directly into a visual mapping tool such as the Commons Sensor. This would build both participants environmental awareness and a more fine grain record of heat experiences in built and social environments.” (MUURS, 2018. P. 36)
References	PDF has a formatting encryption – for a list of references please refer to page 38 – 39 of the report.

19. Urban Heath Islands: differentiating between the benefits and drawbacks of using native or exotic vegetation in mitigating climate. University of Wollongong, School of Biological Sciences Aguier, Axton Conrad, 2012	 UNIVERSITY OF WOLLONGONG School of Biological Sciences Urban Heat Islands: Differentiating between the benefits and drawbacks of using native or exotic vegetation in mitigating climate. By Axton Conrad Aguiar. B. MarSc This thesis is presented as part of the requirements for the Award of the Degree of Master of Science (Research) From the School of Biological Sciences University of Wollongong 2012 i

What	“This thesis investigated whether there was an advantage or disadvantage of using exotic vegetation over native vegetation in green city plans for the Illawarra region… Two field based experiments were carries out to compare native and exotic vegetation at a local level. The ameliorating effect of native and exotic trees was compared using an IR imaging camera. Surface heat under trees was measured on hot (27 – 35 degree Celsius) and normal days (18 – 24 degree Celsius days) and compared between natives and exotics.” (Aguier, 2012, P 9) “The second experiment compared whether native or exotic vegetation was better adapted at surviving increasing temperatures. This was done by comparing the spectral signatures of native and exotic vegetation in two seasons; spring (normal/ average temperatures) and summer (hot temperatures). “ (Aguier, 2012, P 10) “A lab-based experiment (lab experiment 1) was conducted to identify whether vegetation undergoing heat stress expressed any diurnal recovery or any adaptation to reduce heat stress during an ongoing heat event.” (Aguier, 2012, P 10) “The aim of this review is to present a review of the literature that is available on the factors that affect UHIs and the methods being employed to mitigate them. There will be particular focus on the most significant findings and gaps in the literature to try and highlight future

	research areas in the field." (Aguier, 2012, P 14)
Findings	1. In response to field experiment 1: "There was a difference between exotic and native vegetation in their ameliorating effect and this effect varied over season and prevailing temperature. There results suggests that there is some characteristics of trees that affect the surface heat under its canopy, for example, density of the shaded region under the tree." (Aguier, 2012, P 9) 2. In response to field experiment 2: "Native and exotic vegetation exhibited different responses to increasing temperatures. Exotic vegetation experienced higher water stress in response to increasing temperature and a subtle change in the composition of leaf pigments whereas native vegetation was less pronounced. the loss of water specifically for exotic vegetation was attributed to an adaptation where the tree uses water to try and buffer against the onset of extreme heat stress." (Aguier, 2012, P 10) 3. In response to lab experiment 1: "The results suggest that native vegetation have an advantage over exotic species in ameliorating the urban heat effect as well as in their ability to cope with heat stress." (Aguier, 2012, P 10) 4. Chapter 1: Literary Review findings: 4.1. "Larger cities have a greater temperature difference from their surroundings (Tran et al. 2006) and city can be 1 degree Celcius to 7 degree Celcius warmer than surrounding areas (Memon et al. 2008). 4.2. "An Urban Heat Island is formed when attributes of an urban environment aid or induce the retention of heat in the area. this heat retention can be achieved from two sources: surface heat (Rosenzweig and Solecki 2006) and atmospheric heat (Oke 1997). 4.2.1. "Surface heating in cities is caused when the sun heats up an area through direct radiation of energy. The incoming solar energy is absorbed and stored efficiently by manmade surfaces such as asphalt and roofing tiles, heating them and storing the heat energy (Rosenzweig and Solecki 2006). On average, surface heat ranges from slightly above air temperature in the shade to between 1 to 20 degrees Celcius aboce air temperature in sunlight, depending on the intensity of sunlight and material propertyies (Rosenzweig and Solecki 2006; EPA 2008). The heated surface transfers heat via convection to the surrounding environment." (Aguier, 2012, P15) 4.2.2. "Atmospheric convection is caused by hot objects in urban areas radiating heat (Velazquez-Lozada and Gonzalez 20016). This does not have to be a surface heated by sunlight; the heat can also be from waste gases from cars, factories and steam from power plants (EPA 2008). Atmospheric temperaute is highly dependent on weather, time of day and wind conditions in an urban environment (Memon et al. 2008). Typically, the effect is weakest in the early hours of the morning when the heat sources have expended all their heat from the previous day and builds up during the day to its highest point after sunset when the heat sources keep the urban area warm. After sunset, rural or native areas cool The temperature difference between native and rural areas for atmospheric temperatures is much less when compared to surface temperatures." (Aguier, 2012 P.17) 4.3. "The detrimental effects of an UHI can be broken down into 3 broad categories; health, economic and environmental.: 4.3.1. Health: "Extreme heat can lead to heat-related stresses on inhabitants, such as, but not limited to, heat stroke sun burn, heat cramps, dehydration and heat-related mortality…The whole of Europe experienced a severe heat wave in the summer of 2003 that resulted in 50,000 deaths. Argaud et al (2007) investigated how heat stroke or exertional stroke played a role in deaths of

thousands during the heat wave and identified that it continued to affect inhabitants up to 2 years after the event (breathing disorders and need for institutional help that was not required before the heat wave)."

" Semenza et al (1996) studied the 1995 heat wave in Chicago which resulted in 700 deaths mostly heat-related. Inhabitants with medical oroblems and the elderly were most at risk.
Both studies outline the risk of heat in urban areas on inhabitants, however, the UHI also induce other health-related effects such as the development of photochemical smog. The heat promotes the evaporation and aerosolizing of volatile compounds from surfaces and facilitates the mixing of these comoounds with pollutants. This smog can then adversely affect inhabitants with respiratory diseases/ disress related problems such as asthma. (A.H Rosenfeld et al. 1995)."
(Aguier, 2012, P.17)

4.3.2. Economic:
"Increasing heat in an urban centre leads to increased energy consumption as air conditioners work against an even larger heat gradient to keep buildings at optimal temperatures for the inhabitants. Payton et al. (2008) found that UHIs affect the real estate value of a city. Unpleasant hot conditions as well as increased electricity costs per year dissuade possible inhabitants." (Aguier, 2012, P.18)

4.3.3. Environmental:
"UHI decreases air quality and promotes the formation of smog and can infience local weather by increasing humidity, precipitation rate and affecting local wind patterns….
UHI also affect the surrounding ecosystems and wildlife; the increased heat and changing precipitation patterns can make vegetation prone to fire and can push species outside their thermal tolerance range (Valle-Diaz et al. 2009). Another majoy environmental concern is the degradation of water quality buy thermal polluition due to surface heat. Rain water that falls in the city does not seep into the ground but runs over anthropogenic surfaces that are usually impervious to water and at higher temperatures, picking up additional heat loads, dust and chemicals (Finkenbine & Atwater 2000). This water can be dumped into rivers and streams increasing the water temperature (Krause and Lockard 2007) affecting the life cycles of organisms living in the stream/ river. (Aguier, 2012, P.18)

4.4. "The factors that affect UHIs can be split into 2 groups; controllable and uncontrollable (Memon 20018).
Controllable: Vegetation, materials, city structure, anthropogenic heat.
Uncontrollable: Season, wind, cloud.

4.4.1 Vegetation:

"Vegetation plays an important role in controlling the temperature of an area *X. Zhang et al 2009; X. X. Zhang et al. 2010; Mirzaei & Haghighat 2010)…Shading lowers surface temperatures by reducing the amount of incoming solar radiation that hits the surface below the tree. The leabes on the trees have a higher reflectance rate compared to manmade surfaces. Only 30% of the sun's energy reaches the ground surrounding the tree, as the rest is either absorbed by the tree or reflected back to the atmosphere (EPA 2008)…
…Scott et al. (1999) showed that difference in asphalt temperature between a shaded and un-shaded region can get up to over 20 degrees Celsius and shading a parking lot reduced any parks car's internal temperatures by up to 40%."
(Aguier, 2012, P.19)

"The second way in which trees affect temperature is through the process of evapotranspiration. Trees use evapotranspiration to primarily draw water up through the roots to the leaves where it is needed for photosynthesis. Evapotranspiration is also one of the mechanisms by which a plant can thermos regulate itself by converting water to water vapour dissipating the stored heat (Taha 1997). Surface air temperature in the canopy was 1 to 2 degrees Celsius cooler than surrounding air temperatures (Kurn et al. 1993). Evapotranspiration not only reduces the heat build-up in an area, but also reduces the amount of runoff water around the plant." (Aguier, 2012, P.20)

4.4.2. Materials:

"The composition of an object plays an important role in how an objects interacts with incoming radiation from the sun. Most of the sun's energy reaching the earth comes in the visible and infrared part of the spectrum (Lean 1997). Incoming IR radiation is responsible for heating surfaces and objects (Golden and Kaloush 2006; H Akbari et al. 2001; Kikegawa et al. 2003). Material properties such as solar reflectance, emissivity and heat capacity determine how material deals with heat.
Objects with high solar reflectance reflect most of the incoming heat enetgey and hence less heat is stored I the object (Chudnovsky et al. 2004). Light coloured objects reflect more visible energy when compared to dark objects. (Chudnovsky et al. 2004). "

"Asphalt or concrete have a solar reflectance of somewhere between 5 to 50% which means up to half of the incoming energy is stored in the material as heat (EPA 2008; Levinson & Hashem Akbari 2002). The range of reflectance is high because all building surfaces change over time and surfaces collect dust (concrete), becoming darker and reducing the albedo (Levinson & Hashem Akbari 2002)."
(Aguier, 2012, P.20)

"Emissivity is the rate at which an object releases its stored energy. An object with high emissivity will radiate more heat per unit of measure when compared to an object with low emissivity at the same temperature…
An object is in thermal equilibrium when the absorbed heat energy is equal to the radiated heat energy, hence the object does not gain or lose any heat and the temperature of the object remains stable. High emissivity in an object is a good attribute to reduce UHI as it reaches its thermal equilibrium at lower temperatures.

There is very little research done on emissivity as most building materials have an inherently high emissivity with the exception of metals. In most of the newer building procedures modified alloys or metals that have a higher thermal emissivity are used. For example, anodized aluminium is being used for window frames to help reduce heat build-up around windows.

Most building materials have a higher heat capacity when compared to soil or natural materials. Native soil and vegetation readily lose their heat when the sun goes down, whereas, urban materials have a much larger storage of heat and take longer to lose their heait; leading to a higher night-time temperature. Temperatures in the early mornings in Melbourne CBD was 4 degrees Celsius warmer than the surrounding rural areas just before sunrise (Torok & Morris 2001)."
(Aguier, 2012, P.22)

4.4.3. City Structure:
"Urban geometry affects UHI indirectly by determining how materials and anthropogenic heat contribute to the UHI. The urban landscape dictates how wind flows through the city, how much solar radiation a surface receives and a surfaces ability to emit radiation back into space.

	A good layout with a lot of space among buildings will allow good airflow between buildings, reducing the formation of atmospheric heat islands. A dense city will cause anthropogenic heat, as well as heat released from surfaces, to be trapped in the city, increasing the heat. The low air movement also means that ground level ozone and other chemicals released into the air do not get purged and collect in the city forming smog…. …In a well planned city the increase spaces between the buildings will allow the surfaces to release radiation directly into space." (Aguier, 2012, P.22) 4.4.4 Anthropogenic Heat: "Anthropogenic heat has been recognized as an important factor that affect UHI (Tabe 1997; Ferreira et al. 2010; Deque. 2007). Anthropogenic heat includes heat from exhaust humes from cars, factories and heat produced by the activity of people living in the area (cooking, air conditioning etc). The waste heat increases atmospheric heat in and around the city. Kikegawa et al (2003) found that a reduction in the waste heat of air conditioners could result in a temperature decrease of 1 degree Celsius and an efficiency increase of 6%." " Ferreria et al (2010) investigated the anthropogenic energy flux in Sao Paulo and found that human metabolism resulting in 9%, vehicular sources resulted in 50% while stationary sources, such as air conditioners, resulted in 41% of anthropogenic energy." (Aguier, 2012, P.23)" 4.5. "All the mitigation strategies focus on altering the controllable factors to try and influence the UHI effect. The 3 main strategies are green housing, urban trees and cool roof, road and pavement schemes that involve the use of materials with increased reflectance and high emissivity." (Aguier, 2012, P.23) 4.5.1. Green Roof Schemes and Urban Trees (Vegetation) "Of the controllable factors that influence UHI, vegetation is the one most used to try and mitigate UHIs in already developed areas (Scott et al. 1999; H Akbari et al. 2001; Sandifer 2002; X. X. Zhang et al. 2010). Most of the methods involve growing trees on or around man-made structures. (H. Akbari et al. 2001; Sandifer 2002; A. H Rosenfeld et al. 1995). The green roof scheme being developed in the USA, China, UK and Australia concentrates on growing plants on the roofs of houses and buildings to increase their solar reflectance and reduce the heat that the building absorbs directly. Planting urban trees increases the greenness of an urban environment." (Aguier, 2012, P.23) "Both schemes offer direct benefits of reducing surface temperature due to shading, however they also reduce air temperature due to transpiration, improve water quality by providing areas in which water can drain into the soil and also reduce smog and dust pollution. While the cost of planting and maintaining the trees can be high, they can offer some serious savings in terms of electricity usage. vines covering a wall help reduce its temperature by 20 degrees Celsius (Sandifer 2002). Sailor (2008) simulated the same scenario using a computer model and found an increase in soil thickness increased insulation which reduced both heating and cooling demands throughout the year. The benefits of trees are not only expressed during the hotter months but also during winter where the trees provide a wind shield for

the house, reducing heating energy required in the house. Akbari and Taha (1992) studied the effect of wind shielding in 4 Canadian cities and found that the shielding effect reduced the heating electricity usage by 10 – 15%."
(Aguier, 2012, P.24)

"Planting urban trees reduces the carbon footprint and air pollution and increases aesthetics of the location and can reduce the crime rate in areas. Donovan and Prestemon (2010) investigated 2,813 single family homes to try and determine the relationship between trees and crime rate. They found that while view-obstructing trees increased crime, larger trees resulting in reduced crime rates."
(Aguier, 2012, P.24)

"The main issues with green city plans is proper species selection; areas with dry climate should avoid trees that require abundant water and stick with more drought resistant species. Pataki et al. (2011) used sap flow sensors to measure the water use of different species of trees. Planting trees under power lines or with water pipes under them may cause issues if larger species are planted. Some trees emit volatile organic compounds that might add to the smog and affect people with respiratory diseases."
(Aguier, 2012, P.24)

4.5.2. Cool roofs, roads and pavements

"Cool roof schemes are designed to reduce the amount of heat that is transferred directly to the building itself. Cool roof schemes focus on making roods out of materials and colours that have a high albedo. Santamouris et al (2011) found that houses with conventional roofing experienced a thermal range of 25 degrees Celsius during a typical summer day. This was reduced to a range of 8 degrees Celsius by using materials developed with higher reflectance."
(Aguier, 2012, P.24)

"The use of a high reflectance material does not necessarily incur a high cost. Bretz, Akbari and Rosenfeld (1997) found that there was little cost involved in converting traditionally built up roofs or single ply roofs to high albedo surfaces, as a pain coat or a lighter colour tile in the case of single ply would increase albedo. Whole albedo can be increased by lightening the colour, there are some anthropogenic materials that even when light, have a high solar absorption, e.g. asphalt. White asphalt absorbs 75% of incoming solar radiation due to asphalts inherently good thermal characteristics to absorb and retain heat. (S. Bretz et al. 1998)."

"Cool road schemes reduce the absorption of asphalt by using highly reflective aggregate in the asphalt…New light coloured pavements have a reflectance value of over 75%, reducing heat build-up (Garber et al 2011). "
(Aguier, 2012, P.25)

"Akbari et al (1997) studied the shadinfg effects of trees on 2 households by collecting temperature data from both inside and outside the house as well as the roof. They also collected electricity usage for cooling appliances such as the air conditioner. The change in microclimate due to applying high albedo coating resulted in an 80% saving daily and a 25% reduction in peak power usage."

"Parker and Barkaszi (1997) modified the roofs of residential buildings with high albedo coatings and found an average saving of 7.4KWh/day with a reduction in energy used by air conditioners ranging from 2 – 43%."

(Aguier, 2012, P.25)

5.Chapter 1 – Conclusion:

5.1 “While all these factors are important to mitigate the urban heat island effect, only vegetation schemes such as building green roofs and creating green cities are feasible for already developed metropolitan cities. The schemes can be developed and built around already existing infrastructure hence reducing the UHI without changing the structural elements of the city”
(Aguier, 2012, P.25)

5.2 “H. Akbari & Konopacki (2005) reported that with the introduction of UHI mitigation measures, it was possible to reduce the energy output of Houston by 700MW which equates to around 80 million US dollars annually. Another stufy by Akbari (2005) used computer models to simulate the electrical savings due to street trres and cool surface schemes. He estimated that both schemes when fully implementred would save around 100 US dollars annually per house, which would amount to 5 billion US dollars annually in the whole of the USA.”
(Aguier, 2012, P.25)

6. Chapter 2: The effect extreme heat events on plants stress in the Illawarra.

“The study investigated the interaction between extreme temperature events (ETE) and stress levels of plants. Bureau of Metrology weather data was used to identify days of extreme temperature (>35°C) and normal days (22-25°C) and remoted sensed data (Landsat images) was compared for these groups.

Four extreme temperature days were compared to four random normal days over four different habitat types that represented an urbanized gradient. Five different indices were used to calculate a measure of vegetation stress. The response of vegetation stress to temperature over different habitat types was not significant; however, all indices did show a significant difference between habitat type and greenness.

The effect was most pronounced in the NDWI index which was able to detect a change in water levels in plants between hot days and normal days over all habitat types.

It was concluded that while ETE might have a significant effect on plant stress levels, there are other factors such as water availability and plat condition that act as a buffer against heat stress.”
(Aguier, 2012, P.27)

6.1 Introduction:

“Over the last 20 years, there has been a small but constant change in climate globally. (temperature precipitation etc) (Colombo 1999, IPCC 2007). While ecological communities and human society can adapt to these small changes in climate (Jump 2005, Woodroffe 2007 and Hughes et al. 2003), it is the extremes of climatic conditions that have the greatest impact on ecosystems and human society (Bassow 1994, Meehl 2004, Luber 2008).

In recent years there has been a marked increase in the number, duration and intensity of extreme events (X. Xu et al. 2011, Brunetti 2004). With modelling suggesting that extreme temperature events will become ten times more frequent by 2070 (Deque 2007).

	(Aguier, 2012, P.28) 6.2 ETE: “A weather phenomenon at the extremes of the historical climate distribution of an area is termed an extreme temperature event (IPCC 2001). The IPCC classifies extreme temperature events that are extremely rare and only occur 5% of the time. However with anthropogenic factors such as greenhouse gasses and urban heat islands influencing climatic patterns, temperatures classified as extreme temperature events (ETEs) in the past might be normal temperature days in the present or future due to a shift in the mean climatic temperature of the area.” (Aguier, 2012, P.28) (Figure 6 – from IPCC 2001: The scientific basis, ch 2.7.1) might be a good one to include in our report to describe the increase in mean temperature days and to further describe the shift in how we describe ETEs) “The Australian Bureau of Meterorology classifies an extreme heat event as 3 consecutive days with temperatures over 29°C for the Wollongong region. “ (Aguier, 2012, P.29) “Extreme heat events (EHE) can have serious consequences (Argaud 2007, Dematte 1998). The heat wave that Europe experienced in 2004 resulted in over 14,000 deaths in France alone (Arguard 2007)….In these cases the majority of deaths/ damage occurred in heavily urbanised areas. The main reason for this is the compounding effect that urban heat islands (UHI) have with an EHE.” (Aguier, 2012, P.29) “In an UHI the change in surface structure from native to man-mande building surfacses such as asphalt and concrete leads to a build-up of heat that can be from 1 – 20°C hotter than the surrounding native regions (HARC 2009).” (Aguier, 2012, P.30) “ETE’s also have detrimental effects on plant and animal communities (Wollenweber 2003, Mills 2009). In Melbourne 2009, vegetation in and around the CBD experienced extreme heat mortality due to temperatures above 40°C that lasted 4 days.” (Aguier, 2012, P.30) 6.3 Plant Heat Stress: “For a plant, heat stress occurs when the increase in temperature is detrimental to either plant function or development (Hall 2001). The level of heat stress depends on the intensity, duration and the rate of temperature increase (Wahid 2007, Hall 2001). For a plant as a while an increase in temperature increases the evapotranspiration rate of the plant. This leads to increased water use and eventually water stress.” (Aguier, 2012, P.30) “At a cellular level heat affects photosynthetic cells by disrupting the process taking place in photosystem II (PSII) causing rapid reprogramming of cellular activity to ensure cell survival. Heat also affects membrane function and increases fluidity in cells affecting stomatal control as well as transportation of vital nutrients around the plant (Farquhar & Sharkey 1982). At temperatures over 45°C tissue

	death takes places with the denaturing proteins in cells and lipids in cell membranes (Timperio 2008). The increased heat can also affect the plant function by pushing the enzymes found in the chloroplasts and mitochondria outside their temperature range. This will inhibit protein synthesis leading to both loss of function, development and eventually plant death (Wahid 2007).” (Aguier, 2012, P.30) “”Elevated temperature can increase transpiration (Calvet 2008, Riederer 2001), increasing water loss reducing turgidity and plasmolysis of cells. Heat stress is also closely related to water stress due to the increased loss and use of water.” (Aguier, 2012, P.30) 6.4 Remote Sensing to monitor Plant Stress: “Most studies of plants are laboratory-based where the plants are put under specific EHE conditions and their responses are recorded. Remote-sensing can provide a useful tool for measureing landscape responses to EHEs. Multi/ hyper spectral sensors are able to determine plant stress levels by recording changes in lead reflectance in the visible and IR regions of the spectrum caused by stress (BOM 2011, Kidwell 1997).” (Aguier, 2012, P.30) “The behaviour of a plant to a stree event and how this is manifested in the spectrum, allows for the use of remote sensors to detect how vegetation responds to heat stress (NASA 2011b). A healthy plant will absorb most of the blue and red part of the spectrum and reflect most of the incoming IR energy, however a stresses plant will have a lower number of chloroplasts hence absorb less blue and red energy and a lower amount of IR radiation will be reflected due to the changes in cell structure (Huete 2006, NASA 2011b).” (Aguier, 2012, P.31) “Remote sensing data can also be sued to distinguish among different types if plant species due to differences in the chlorophyll, cell structure and moisture level between plant species…. This ability to distinguish healthy and stressed plants of different species makes collecting data on EHE using remote sensing is a valuable tool in understanding the dynamics of how different plants interact with ETE.” (Aguier, 2012, P.32) 6.4.1 Methodology: (For detailed explanation of the methodology refer to pages 33 – 36. 6.4.2 Vegetation mapping typologies: a) Coastal Vegetation: consisting mainly coastal plants (all sites were dominated by mangroves) b) Inland Vegetation: consisting of mainly trees with dense canopies c) Urban: Very little vegetation – most sites had between 5-15% vegetation d) Industrial: no vegetation e) Suburban: housing with large gardens and lawns 30-50% vegetation. 6.4.3 Results: Inconclusive – remote sensing does not detect plant stress.

	"NDWI may indicate an increase in transpiration which can alleviate heat stress. In the Australian context mnost native plants have a high resilience to drought and extreme temperature. Bush fires and droughts are common environmental factors that Australian native plants are exposed to and have adaptations to deal with." (Aguier, 2012, P.39) "There is abundant literature on how forest fires and heat generated by these fires affect plants (Williams 1999, Pyke 2010) as well as the effects of drought on plants and their responses (Munns 2002, Munné 2004)" "Most native Austrslian plant life cycles revolve around forest fires and the plants have grown adapatations to help deal with the heat in forest fires that can reach 500°C (Gignoux 1997). Some of these adaptations include heat shock proteins (Timperio 2008) glossy leaves reflect heat and waxy thin leaves that help reduce water loss through transpiration. This resilience towards heat and drought found in native Australian plants make them better able to withstand heat events." (Aguier, 2012, P.39) 7. Chapter 3: Urban Heart Islands: A comparison of the ameliorating effects between native and exotic street trees. "With over 3.6 billion people living in urban environments it has become increasing important to mitigate factors that negatively influence the urban environment. Green plans and green roof schemes have become increasingly popular over the last decade in combating the increase in temperatures associated with urbanisation, known as the urban heat effect." (Aguier, 2012, P.41) This chapter looks at "differences in using exotic over native vegetation in green city plans to ameliorate the urban heat effect and if the strength of any ameliorating effect changes with ambient temperature." To that end, the surface temperature of asphalt around 6 species of street trees (3 exotic and 3 native) at 8 sites each was recorded using a FLIR Infrared camera over 2 seasons." (Aguier, 2012, P.41) "I found that surfaces under native vegetation exhibited lower temperatures when compared to exotic vegetation. The results suggest that there was some characteristics of native vegetation such as density of shade that influenced the heat on the surfaces. I concluded that native vegetation is better at ameliorating surface heat islands which will be an important consideration for green plans." (Aguier, 2012, P.41) 7.1 Introduction: "The UN's Department of Economic and Social Affairs (Population division) (United Nations 2011) indicates that 52% (3.6 billion) of the world's population now inhabit urban areas. The population will increase to a total of 6.3 billion by 2050 (UN 2011). With so many people living in urban environments it's important to better understand the various factors that influence the temperature of these areas." (Aguier, 2012, P.41) "Surface temperature modulates atmospheric temperature in an urban environment by influencing the air that is in contact with it. This interaction has various repercussions such as influencing the energy exchange from buildings, affecting the internal climate of buildings

	(Guan 2012, Kikeqawa et al. 2003; Kolokotroni et al. 2012), creating diverse and erratic microclimates (Colombo et al 1999; Giridharan et al. 2004) and affecting the comfort and wellbeing of people living in the city (Tomlinson et al. 2011; Frumkin 2002; Mills 2009). The phenomenon where the urban temperature is hotter than the surrounding rural temperature is called the urban heat island (UHI).” (Aguier, 2012, P.41) “With IR imaging technology becoming more widely available, it has allowed for a greater understanding of the urban microclimate. Platform-based IR sensors, such as satellite sensors, give us a greater spatial resolution over the whole urban city; while improvements in hand held IR imaging technology means that even at a low spcial resolution a lot more detail can noe be captures (compared to sport measurements of IR guns and surface thermometers).” (Aguier, 2012, P.42) “Decreases in the intensity of the UHI may be achieved by increasing the albedo of urban surface materials (Haider Taha et al. 1988; Haider Taha 1997; Santamouris et al. 2011), increasing urban vegetation cover (H Akbari et al. 2011; Shashua-Bar & M. Hoffman 2003; Tsiros 2010), reducing anthropogenic heat (Ferreira et al. 2010; Haider Taha 1997), and designing city structure (Shashua-Bar & M. Hoffman 2003).” (Aguier, 2012, P.42) “It is widely accespted that increased vegetation is the most cost effective and beneficial way of combating the UHI effect by evaporative cooling and shading, it also reduces runoff from trees, reduces CO2 and noise pollution, increase wellbeing of the inhabitants, and increases the economic value of the real estate (Payton et al. 2008” (Aguier, 2012, P.42) “This study hopes to clarify whether there is a difference in shade between native and exotic vegetation by assessing the surface temperatures under the tree. This will also help to assess whether native or exotic vegetation are better at n=mitigating the urban heat island effect.” (Aguier, 2012, P.42) “The main objectives were to: 1) compare the ameliorating effects of native vs. exotic trees, and 2) assess the effect of ambient temperature has the capacity of trees to ameliorate surface temperatures. Temperatures of asphalt surfaces in the sun and shade near plants were compared to identify the effectiveness of trees in reducing surface temperatures.” (Aguier, 2012, P.43) 7.2 Methods: “Species of street trees were ranked based on how popular they were in local green plans as well as abundance in the Illawarra region. Six common species were chosen for this study; three exotic and three native.” (Aguier, 2012, P.43) Tree species used: Platanus x hybrida (Plane Tree) - Exotic Liquidambar styraciflua (Sweet gum/ liquidambar) - Exotic Jacaranda mimosifolia (Jacaranda) – Exotic

	Melia azedarach (White Cedar) – Native Melaleuca quinquenervia (Broad-leaved paperbark) – Native Tristaniopsis laurina (Water Gum) - Native
Proposed Strategies	Accuracy: “In the experiment it was decided to avoid using fixed weather stations or satellite-based sensors to either get a genral idea of the atmosphereic temperature in a region or as a data source to measure the urban heat effects. Instead hand held sensors were used to give a better estimate on how hot the atmosphere in the sites actually were.” (Aguier, 2012, P.45) “A study done by Lathlean et al. 2011 found that satellite based estimates were 1-6°C over the actual air temperature whereas fixed weather stations were up to 23°C (on average 4°C lower) lower than the actual air temperature.” (Aguier, 2012, P.45) 7.3 Results: “The surface temperature in the shaded and un-shaded regions around a tree was affected by prevailing ambient temperature. Another trend was shaded regions on hot days had similar temperatures to unshaded regions on cools days.” (Aguier, 2012, P.46) “Within the shaded and unshaded areas there was a significant difference in the temperature of the surface heat island among species. Native and exotic species did not differ in their influence on temperature in the unshaded region, however, the shade under native trees was cooler then under exotic trees.” (Aguier, 2012, P.47) “Native species (shaded or unshaded) did not differ in their impact on temperature, however, for exotic species, liquidambar trees tended to have warmer shaded and unshaded areas than other species.” (Aguier, 2012, P.47) “There was no difference in temperature under exotic and native trees on normal temperature days, however on hot days, the exotic vegetation had significantly higher surface temperatures around them when compared to native vegetation. On a normal day under both native and exotic vegetation had a mean surface temperature surfaces had a mean of around 27°C, however on a hot day surfaces under exotic vegetation were on average 2°C higher than native vegetation.” (Aguier, 2012, P.48) “There was also a difference among species in their ameliorating capacity. This difference was only exhibited in the exotic street trees where *J. mimosifolia* and *Platanus x hybrida* had significantly lower temperature under their canopy when compared with *L. styraciflua*.” (Aguier, 2012, P.49) “The ameliorating effect of the trees were limited to the shady area under the trees; the shaded region exhibited the greatest variation between native and exotic, while further away in the sunlit areas, the influence of the trees’ shade was not different. This was expected as it is the shade that prevents solar radiation heating up the surface (H Akbari et al. 2001).”

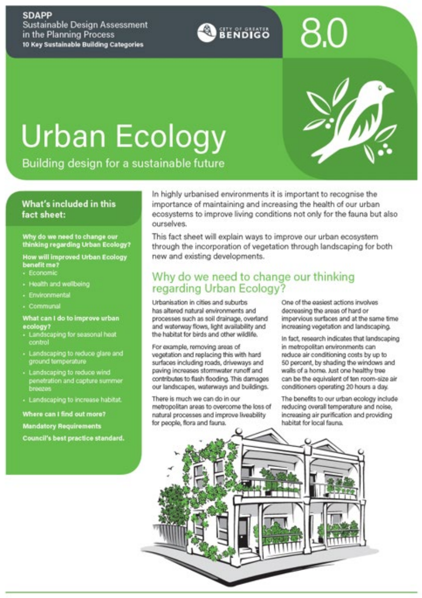
	"Differences in transpiration rates can lead to different atmospheric temperatures under the tree creating a temperature potential for heat to be transferred from the surface to the atmosphere. The greater the temperature difference, the faster the heat is transferred. Trees with higher exaoptranispiration should have lower atmospheric temperatures (ambient air temperature) around them allowing more heat to transfer from the surface to the atmosphere (Haider Taha 1997; Oke 1987)." (Aguier, 2012, P.50) " Ataki (2011) also found that transpiration rate and water use varied amongst different species, categorising *Platanus spp* as one of the high use water species. However, in the experiment it was found that *Platanus spp* and *Liquidambar spp* had highest surface temperatures in the shaded region when compared to the natives and the other exotic, suggesting that transpiration rates may not account for the patterns that were found." (Aguier, 2012, P.50) 8. Chapter 4: Comparing the Effects of Heat Stress on Native and Exotic Vegetation in a Lab and Fielf Setting. " While an urban forest has benefits, an urban area is a challenging environment in which to grow and survive. Trees must contend with resource shortages and disturbances that lead to increased stresses (Pataki et al. 2011). Water shortages are caused by limited drainage points and the impervious top layer of asphalt or concrete which directs water into drains. Heat stress may be caused by the urban heat island. With global temperatures increasing and conservative models predicting a global temperature increase of 2-4°C in the next 50 years (Meehl et al. 2000), added to the fact that extreme heat events are becoming more common and severe (Meehl et al. 2000), the interaction between the urban heat island and increased global temperatures may increase heat stress in urban plants." (Aguier, 2012, P.53) "One solution to the problem of detecting heat stress in pants is the use of remote sensing technology. Hyperspectral data obtained from imaging spectrometry is now widely used in the field which can measure indicators such as leaf pigments (Sims and Gamon 2002; Blackburn 1999; Stone & Chisholm 2005) and cell break down to detect plant stress (Stone and Chisholm 2005; Coops et al. 2004)." (Aguier, 2012, P.54) 8.1 Methedology: (For methodology refer to pages 54-64) 8.2 Results: "Natives exhibited lower stress levels with increasing temperature in both the field and laboratory settings…. The different stress levels observed un the NIR between experiments suggests that street trees could be using water as a buffer against heat damage to the structure of the leaves (Hunt & B. Rock 1989; Riggs & Running 1991). " (Aguier, 2012, P.66) "Water (drought) stress can also explain why exotic trees had higher stress levels. Ataki (2011) found that transpiration rate and water use varied amongst different species, categorising some of the exotic species used in this experiment such as the *Platanus spp*. as one of the high use water species." (Aguier, 2012, P.66)

	“The difference between natives and exotics was strongly affected by individual species responses. *T. laurina* (native) exhibited lower stress levels during hot days than other natives, suggesting this species may be more acclimatized to hotter temperatures. “ (Aguier, 2012, P.67)
References	(PDF is locked, cannot copy and paste references. Refer to pages 68 – 82 for reference schedule.

24. Urban Ecology – Building Design for a sustainable future.

SDAPP
Sustainable Design Assessment in the Planning Process
10 Key Sustainable Building Categories

City of Greater Bendigo, 2015


SDAPP
Sustainable Design Assessment in the Planning Process
10 Key Sustainable Building Categories

CITY OF GREATER BENDIGO

8.0

Urban Ecology

Building design for a sustainable future

What's included in this fact sheet:

Why do we need to change our thinking regarding Urban Ecology?

How will improved Urban Ecology benefit me?
- Economic
- Health and wellbeing
- Environmental
- Communal

What can I do to improve urban ecology?
- Landscaping for seasonal heat control
- Landscaping to reduce glare and ground temperature
- Landscaping to reduce wind penetration and capture summer breezes
- Landscaping to increase habitat.

Where can I find out more?

Mandatory Requirements

Council's best practice standard.

In highly urbanised environments it is important to recognise the importance of maintaining and increasing the health of our urban ecosystems to improve living conditions not only for the fauna but also ourselves.

This fact sheet will explain ways to improve our urban ecosystem through the incorporation of vegetation through landscaping for both new and existing developments.

Why do we need to change our thinking regarding Urban Ecology?

Urbanisation in cities and suburbs has altered natural environments and processes such as soil drainage, overland and waterway flows, light availability and the habitat for birds and other wildlife.

For example, removing areas of vegetation and replacing this with hard surfaces including roads, driveways and paving increases stormwater runoff and contributes to flash flooding. This damages our landscapes, waterways and buildings.

There is much we can do in our metropolitan areas to overcome the loss of natural processes and improve liveability for people, flora and fauna.

One of the easiest actions involves decreasing the areas of hard or impervious surfaces and at the same time increasing vegetation and landscaping.

In fact, research indicates that landscaping in metropolitan environments can reduce air conditioning costs by up to 50 percent, by shading the windows and walls of a home. Just one healthy tree can be the equivalent of ten room-size air conditioners operating 20 hours a day.

The benefits to our urban ecology include reducing overall temperature and noise, increasing air purification and providing habitat for local fauna.

What	This factsheet: 1. Introduces the concept of Urban Ecology 2. Outlines the benefits of an improved Urban Ecology 3. Provides tools for personally improving the Urban Ecology 4. Provides a directory to those who seek more information 5. Outlines Bendigo Council's best practice standards
Findings	1. "Urbanisation in cities and suburbs has altered natural environments and processes such as soil drainage, overland and waterway flows, light availability and the habitat for birds and other wildlife. For example, removing areas of vegetation and replacing this with hard surfaces including roads, driveways and paving increases stormwater runoff and contributes to flash flooding. This damages our landscapes, waterways and buildings." (City of Greater Bendigo, 2015, P.1) 2. "One of the easiest actions involves decreasing the areas of hard or impervious surfaces and at the same time increasing vegetation and landscaping. In fact, research indicates that landscaping in metropolitan environments can reduce air conditioning costs by up to 50 percent, by shading the windows and walls of a home. Just one healthy tree can be the equivalent of ten room-size air conditioners operating 20 hours a day.

The benefits to our urban ecology include reducing overall temperature and noise, increasing air purification and providing habitat for local fauna."
(City of Greater Bendigo, 2015, P.1)

3. Benefits of an improved Urban Ecology:

3.1 Economic:
The economic benefits of having trees in the proximity to buildings can be both direct and indirect:

Air-conditioning costs for cooling can be up to 50 percent lower in a tree-shaded home as the home is provided with effective shading of windows and walls.

Trees increase in value from the time they are planted until they mature. The housing market acknowledges that landscaped homes are more valuable than non-landscaped homes.
The savings in energy costs and the increase in property value directly benefit each home buyer.
3.2 Health and Wellbeing:
Studies show that green spaces (plants, trees, parks etc.) are good for human health and wellbeing. What's more, green spaces in cities have been closely linked with improved physical, social, and mental well-being. Studies have found that hospital patients with a view of green space from their window, compared with a wall, needed less pain medication and recovered faster from surgery.

3.3 Environmental:
Vegetation in cities assists in moderating ambient temperatures. This reduces the urban heat island effect which is caused by pavements and buildings absorbing heat. For example, effective shading of a window or home can negate the need to have air-conditioning.

Trees and shrubs can also be carefully selected to:

-reduce glare

-reduce penetrating winds

-control airflow

-improve air quality

-sustain a viable ecosystem for birds, small animals, and insects.

3.4 Communal:
Metropolitan vegetation and landscaping often provides the following communal benefits:

-providing privacy

-emphasizing or screening out views

-reducing glare and reflection

-directing pedestrian traffic

-complementing and softening the built environment.
(City of Greater Bendigo, 2015, P.2)

Proposed Strategies	Ways of improving the Urban Ecology: 1. Landscaping for seasonal heat control: - It is best to protect north, east and west facing windows as this will help protect against hot summer sun. - Deciduous vegetation will provide summer shade but allows winter sun to penetrate the building. - Trees with dense foliage create more shade and therefore have greater cooling abilities. - As space is often limited in urban developments, vegetating courtyards as much as possible is an effective way to reduce temperatures in your courtyard and internal living spaces. - Vertical shading is most appropriate for east and west walls and windows to protect from hot summer sun at lower angles e.g. trees, shrubs and vines supported on a frame. - Utilising plants that grow on walls (such as ivy) can act as thermal insulation for a building. - Horizontal shading is best for north facing windows e.g. deciduous vines grown over a pergola. - Tall evergreen trees should not be planted too close to north-facing windows as they create too much overshadowing in winter. (City of Greater Bendigo, 2015, P.3) 2. Landscaping to reduce glare and ground temperature: Glare occurs when intense sun reflects from surfaces such as paving, roofs and walls. Glare can be reduced by increasing ground cover, low growing shrubs, lawns and vegetated roofs and walls. Ground cover planting not only reduces glare, it also decreases surface temperatures. For example, a vegetated courtyard can be 6°C cooler than a paved courtyard. In addition, a vegetated surface allows stormwater runoff to be absorbed into the soil which reduces stormwater runoff, improves stormwater quality and increases soil moisture.

	Green roofs are known to help lower urban air temperatures (heat island effect), provide building insulation and create a habitat for wildlife. (City of Greater Bendigo, 2015, P.3) 3. Green Roofs and Walls: "Green roofs and walls are a great way to not only enhance the local urban ecology but also to improve the insulation of a building. This will keep internal spaces warmer in winter and cooler in summer. In urban areas, green roofs also help reducing the heat island effect, which describes the fact that metropolitan areas are generally warmer than rural areas. This is due to the extensive use of materials, such as concrete and bitumen, that retain heat. There are three types of green roofs: - Intensive roofs, which have a deeper substrate and can support a wider variety of plants but are heavier and require more maintenance. - Extensive roofs, which have a shallower substrate, supporting a lighter layer of vegetation. - Planter boxes on roofs, which can be installed on most accessible flat roofs and often represent a simple alternative to intensive and extensive green roofs. There are two main types of green walls: - Green facades, where a wall or structure is designed to allow for climbing plants to grow onto. - Living walls, where modular systems of growing media are integrated into, or fixed onto, a wall." (City of Greater Bendigo, 2015, P.3) 4. Landscaping to reduce wind penetration and capture summer breezes "-Vegetation can be selected and positioned to control the chilling effects of winter winds and also assist in capturing and harnessing cooling summer breezes. -Things to consider when landscaping to influence winds: Windbreaks are most effective when located at 90° to the direction of the wind. A windbreak with 50–60% density is generally more effective than a solid one, as a solid wall can create turbulence. - Large dense shrubs can be used as windbreaks to the south-west to counter cold winter winds and channel cooling summer breezes. - Medium to large-sized shrubs or trees clipped to form a hedge can provide useful still air insulation and shading when grown close to a wall.

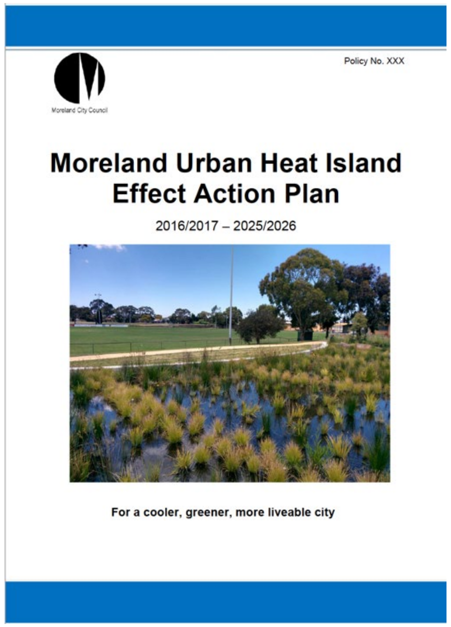
	- Careful positioning of windbreak planting can encourage the entry of desirable summer breezes through the building. - Low shrubs, lawn and ponds to the north will help cool hot summer winds." (City of Greater Bendigo, 2015, P.4) 5. Landscaping to increase Habitat: "In addition to creating larger areas of habitat in local parks and reserves, sustainable gardening around dwellings and buildings can contribute to increasing habitat value and urban ecology. Points to consider to achieve a sustainable habitat garden include: - It is possible to have contemporary gardens, e.g. cottage or formal gardens, and still utilise indigenous plants. - Select plants that are indigenous as they will best suit your local climate and soil. Research what plants will attract native birds and insects. - Complete a site analysis focusing on soil quality, sun, shade and privacy before you choose your native plants. - Get a copy of Council's local plant guide. - Avoid using plants that are known environmental weeds." (City of Greater Bendigo, 2015, P.4)
References	**1.** Save Energy Through Landscape Design Sustainability Victoria www.sustainability.vic.gov.au **2.** Urban Ecology Information Urban Ecology Australia www.urbanecology.org.au **3.** Technical Manual Green Roofs Your Home www.yourhome.gov.au **4.** Sustainable Gardening Information Sustainable Gardening Australia www.sgaonline.org.au **5.** Green Building Council Australia Change in Ecology Calculator www.gbca.org.au **6.** Green Roofs, Walls and Facades City of Melbourne www.melbourne.vic.gov

26. Moreland Urban Heat Island Effect Action Plan

For a cooler, greener, more liveable city

2016/2017 – 2025/2026

Moreland City Council 2016



What	Long term action plan created to mitigate the effects of Urban Heat Island Effect in the Moreland City LGA. The Action Plan is written to have a civilian audience, it defines Urban Heat Island Effect, and provides explanations on potential methods of reducing the effects.
Findings	1. “During heatwaves most parts of the city ccan be four to seven degrees warmer than surrounding rural areas. Detailed analysis of Moreland’s UHIE vulnerability has found that there is an overall high UHIE across the municipality and a high number of extremely hot places; with very few cool places. The ananlysis highlighted that Moreland has a community that is vulnerable to this heat. During long periods of hot weather the UHIE increases heat stress in the community. Most affected are the elderly, the very young and those with pre-existing medical conditions.” (Moreland City Council 2016, P. 3) 2. “The UHIE is driven by a number of key factors: • **A high percentage of solid surfaces e.g. asphalt and concrete** – these surfaces absorb, trap and re-radiate heat. They also prevent rainwater soaking in, reducing water available for plants, which in turn reduces evaporative cooling. 3. • **Limited vegetation** – reduces shading and cooling through evaporation from plants through leaves. • **Urban development pressure** – creates denser urban environments that trap heat and removal of green areas reducing cooling • **Construction materials which hold heat and have low reflectivity** – e.g. terracotta tiles, bricks, bitumen and concrete – these materials absorb, trap and re-radiate heat. • **Dense urban arrangements** – absorbs and traps heat • **Heat production from the activities of people** – produced by vehicles, split air conditioners etc.

	• **Air pollution** – that creates a local 'greenhouse' effect, trapping heat" (Moreland City Council 2016, P. 5) 4. "A stark insight into the multiple risks of heat waves was revealed when more people died in Victoria from heat related illness during the 2009 heatwave than from the devastating bushfires during the same period." (Moreland City Council 2016, P. 5) 5. "Heatwaves kill more Australians than any other natural disasters…they are private, silent deaths that only hit the media when morgues reach capacity or infrastructure fails" (PricewaterhouseCoopers and Australian Federal Department of Climate Change and Energy Efficiency 2011, Report on UHIE). 6. "Tree shade can reduce daytime land surface temperatures by up to 20 degrees celcius" (Ward B, Infrared Thermography Survey for City of Greater Geelong 2015). 7. "Council assets are at risk too. For example, natural assets such as green space and trees are vulnerable due to reduced water and heat stress. Loss of these green spaces can further increase the UHIE. In addition, these assets are where the native animal population live. With no or limited irrigation in a water constrained future these assets and the animals that live in them, are at risk too." (Moreland City Council 2016, P. 5) 8. Measures highlighted as being feasible for Urban Heat reduction included: 1. Vegetation 1.1 Increase Vegetation and protect existing vegetation. 1.2 Increased outdoor landscaping (green roofs and walls 1.3 Improve parkland and open space (irrigated spaces) 2. Water 2.1 Water Sensitive Urban Design 3. Materials 3.1 Use of reflective materials 4. Urbanisation 4.1 Street design – orientation, width 4.2 Evaporative Air Coolers (instead of reverse cycle) 4.3 Public Transport, walking, cycling and electric vehicle use 4.4 Improve building quality to reduce the need for artificial cooling. 5. Social 5.1 Social UHIE policy and education. (Moreland City Council 2016, P. 6) 9. The report highlights three areas that could benefit from enacting UHIE mitigation measures: 1. Economic; reduced energy costs from reduced use of artificial cooling, increased property values and increased retail spending in commercial areas etc. 2. Social: Reduction in heat related illness and fatality, increase in outdoor activity and an improvement in mental wellbeing etc. 3. Environmental: Cleaner, healthier waterways, reductions in air pollution and dust, more water retention in the landscape in a water constrained climate. (Moreland City Council 2016, P. 7) 10. "Moreland already has many existing policies and programs that contribute to addressing the UHIE. A key focus in the Action Plan is working within existing projects to achieve UHIE outcomes." (Moreland City Council 2016, P. 7)

	11. **"Leveraging existing action:** Moreland is already implementing a number of actions that contribute to mitigating and responding to the UHIE: • A street tree planting program, which plants 5,000 new trees across the municipality each year • Water sensitive urban design projects in public spaces • Improving irrigation of open space • Working to encourage a shift away from fossil fuel powered vehicles • Building resilient Council buildings in line with the Moreland Sustainable Buildings Policy • Building community capacity to respond to heat waves through engagement and education • Improving the resilience of buildings and houses within the community through providing advice and support for energy efficiency actions and planning policies for new developments. • We are committed to commence the development of an urban forest strategy late 2016 that will integrate the findings of the UHIE Action Plan and the Street Tree Planting Plan as well as build upon the strong foundations of the Moreland Street Landscape Policy." (Moreland City Council 2016, P. 8) 12. "**Focus on priority areas:** Council will focus on delivering or supporting action in its vulnerable areas. Projects that are driven by other priorities can integrate measures to reduce the UHIE. Through this approach measures can be implemented municipality wide as opportunities arise. Priority areas have been identified using mapping to find the intersection of the following vulnerability indicators: • Hotspots (locations with surface temperatures of 52 degrees or above on extreme heat days) • Social vulnerability (young children aged 0-4, older persons living alone, socio-economically disadvantaged groups, those who aren't fluent in English, those in social housing, census and Socio-Economic Indexes for Areas (SEIFA) data • High human activity (principal pedestrian network, commercial and retail areas, neighbourhood activity centres, bike paths, schools, kindergartens and childcare facilities • Future zoning and population growth changes."(Moreland City Council 2016, P. 8) 13. "New York has mandated that 75% of new and retrofitted rood tops increase the amount of heat they reflect rather than absorb." (NYC Coolroofs, 2016) 14. "Street trees in residential inner Melbourne can reduce summer air temperature underneath by 3 degrees Celsius and reduce heat stress significantly." (Nortom et al, 2013) 15. The report identifies key stakeholders and their roles in responding to the UHIE. Stakeholders include: 15.1. "Federal government: Demonstrate leadership by setting national goals for climate mitigation and adaptation • Incentivize the uptake of electric vehicles • Fund research and development including research into the business case for green infrastructure • Support funding for public transport and green infrastructure • Incorporate UHI mitigation solutions into the National Urban Design Protocol and the planning framework for the Department of Cities and Built Environment" 15.2. State Government:

	• Demonstrate leadership by setting clear progressive positions on climate mitigation and adaptation including green infrastructure, sustainable transport, climate resilient buildings and communities • Support infrastructure development that incorporates active and public transport and water sensitive urban design • Coordinate, support and fund green infrastructure • Undertake action to support vulnerable communities such as those in social housing and schools 15.3. Research Institutions: • Research and development into process and practical innovation for mitigating the urban heat island effect • Partnering with organisations such as local government to develop and apply evidence based solutions are embedded appropriately 15.4. Melbourne Water and Yarra Valley Water, VicRoads, Yarra Trams, Creek Management Committee's: • Develop partnerships to undertake green infrastructure actions • Lead actions on assets under their management • Advocacy for funding to support action 15.5. Moreland City Council: • Implement localised green infrastructure • Improve resilience and performance of Council assets • Integration of green infrastructure and resilient buildings into local policies • Support community and local industry to take action • Collaborate regionally • Advocacy and reporting to build the case for future action 15.6. Moreland Community households and business: • Install localised green infrastructure • Improved resilience in business and residential buildings • Develop greater social resilience to heatwaves • Install heat sensitive domestic water management 15.7. Northern Alliance for Greenhouse Action Moreland Energy Foundation Ltd: • Promote and drive regional plans and actions • Advocacy • Partner with Council to seek external funding for solution delivery • Support community and industry to take action • Community engagement and education 15.8. Council Alliance for Sustainable Build Environments: • Promote and drive regional sustainable building tools, policies, standards and actions • Advocacy

	• Partner with Council to seek external funding for solution delivery" (Moreland City Council 2016, P. 11) 16. In 2014 Monash University researchers produced an UHIE vulnerability map for Melbourne…Risk factors in the study included lack of tree cover, housing types and age, health and socio-economic status of the population." "A more detailed background report is available which includes a report summarizing this work titled "Urban Heat Island Priority Locations, Moreland City Council. October 2015 The research demonstrates that in summer, Moreland has very few cool places and a significant number of extremely hot places (hot spots)….Hot spots are those areas of concentrated heat retention which are emitting the highest Land Surface Temperature (LST) values. The hot spots are areas that registered 52 degrees Celsius or above….By comparison, irrigated areas such as City Oval in Bridges Reserve were measuring 38 degrees Celsius which was the same as the ambient air temperature." (Moreland City Council 2016, P. 11) 17. Moreland City Council have identified five priority areas based on their vulnerability and extreme heat conditions: 1. North Social Vulnerability (not located within a hotspot, but an area of dense public housing). 2. Activity Centers 3. Neighborhood centers/ suburban shopping strips 4. Socially Vulnerable Streets located within hotspots 5. Major industrial areas. (Moreland City Council 2016, P. 18)
Proposed Strategies	Moreland City Council have set goals, with actionable targets and defined key performance indicators to achieve a "cooler and more livable city with improved protection from the heat." **1. Goal 1: Responding to the Urban Heat Island Effect by setting and reviewing actions and targets to meet UHIE strategies through an integrated whole of Council approach** **1.1. Strategy:** Integration of UHIE reduction and responses into existing operations, policies and programs **1.1.1 Targets:** All relevant Council Policies and Strategies are to incorporate relevant urban heat island effect mitigation and adaptation solutions. **1.1.2 KPI's:** • Relevant policies including UHIE reduction and response • Relevant actions implemented **2. Goal 2: Reducing the impact of extreme heat events in Moreland and creating a cooler, greener more livable city.**

2.2. Strategy: Strengthen and build green infrastructure

2.2.1 Targets:

• Increase vegetation cover in Moreland's most vulnerable areas by 35% by 2020 (from Zero Carbon Evolution –ZCE)
Note: This target is subject to review and requires further study to factor in canopy cover and irrigated vegetation information since ZCE was endorsed (action item 2.2)
• Stormwater harvesting infrastructure supplying 30ML/a of treated water for open space irrigation by 2020 (from WaterMap 2020)

2.2.2 KPI's:

• Relevant actions implemented
• Increased tree canopy cover
• Irrigated vegetation

• An increase in stormwater harvested for irrigation

2.3 Strategy: Facilitate cool buildings

2.3.1 Targets: Council will engage with all relevant stakeholders and community to encourage cool buildings and cool roofs

2.3.2 KPI's:

• Relevant actions implemented from this Action Plan
• More cool buildings
• Cool roofs installed

2.4 Strategy: Create Cool Roads and paths

2.4.1 Targets: Moreland will research and investigate the trialing and installing of cool roads and paths infrastructure by 2020

2.4.2 KPI's:

• Cool roads and paths studies reviewed and reported
• Cool roads and path infrastructure integrated

3. Goal 3: Raising community awareness and encourage actions to create a cooler, greener and more livable city

	3.1 Strategy: Foster a heat aware community **3.1.1 Targets:** Increased community action to reduce and respond to the urban heat island effect by the community. **3.1.2 KPI's:** • Relevant actions implemented • Take up of programs and actions to facilitate reduction of the UHIE (e.g. Positive Charge, SDAPP, WaterSMART) (Moreland City Council, 2016, P. 18) Pages 20 – 37 details the actionable items, and stipulastes the Action, the lead unit, the supporting unit, the source of funding, the expected delivery date and the measures of success.
References	1. Adams, MP & Smith PL (2014) A systematic approach to model the influence of the type and density of vegetation cover on urban heat using remote sensing. *Landscape and Planning*, 132, 47-54 2. Aecom for City of Melbourne, (2012) Economic Assessment of the Urban Heat Island Effect and 3. American Council for an Energy Efficient Economy (2014) Cool Cities for Cool Policies: Best Practices for Mitigating Urban Heat Islands in North American Cities, Report no U 1405, 4. Argüeso D, Evans JP, Fita L and Bormann KJ, (2012). Temperature response to future urbanization and climate change, Climate Dynamics, 42, 7-8, pp2183-2199. 5. Barnett G, Beaty M, Chen D, McFallan S, Meyers J, Nguyen M, Ren Z, Spinks A and Wang X, (2013) National Climate Change Adaptation Research Facility, CSIRO Publishing, ISBN: 978-1-925039-16-0 1. Bush, J., Aye, L. and Hes, D., 2015, Mitigating the urban heat island effect with vegetation in Australian cities: A policy analysis framework. Proceedings of the State of Australian Cities Conference, December 2015, Gold Coast. 2. Demuzere m, Coutts AC, Gohler M, Broadbent AM, Wouters H, van Lipzig NPM and Gebert L (2014) The implementation of biofiltration systems, rainwater tanks and urban irrigation in a single layer urban canopy model. *Urban Climate,* 10, 148-170 3. Dimoudi, A & Nikolopoulou, M. (2003). Vegetation in the urban environment: Microclimatic analysis and benefits. *Energy and Buildings,* 35(1), 69-76 4. Loughnan, ME, Tapper, NJ, Phan, T, Lynch, K, McInnes, JA 2013, A spatial vulnerability analysis of urban populations during extreme heat events in Australian capital cities, National Climate Change Adaptation Research Facility, Gold Coast pp.128. 5. Mullaney J, Lucke T, Trueman SJ (2015). A review of benefits and challenges in growing street trees in paved urban environments. *Landscape and Urban Planning,* 134, 157-166 6. Norton BA., Coutts AM., Livesley, SJ., Harris RJ., Hunter AM. & Williams NSG. (2015). Planning for cooler cities: A Framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. *Landscape and Urban Planning,* 134, 127-138 7. Norton B, Coutts A, Livesley S, Williams N, (2013). Decision Principles for the selection and placement of green infrastructure to mitigate urban hotspots and heatwaves, Victorian Centre for Climate Change Adaptation Research 8. Norton, B., Bosomworth K, Coutts A, Williams N, Livesley S, Trundle A, Harris R, McEvoy D (2013). Planning for a Cooler Future: Green Infrastructure to Reduce Urban Heat, Victorian Centre for Climate Change Adaptation Research 9. NYC CoolRoofs, 2016. http://www.nyc.gov/html/coolroofs/html/home/home.shtml

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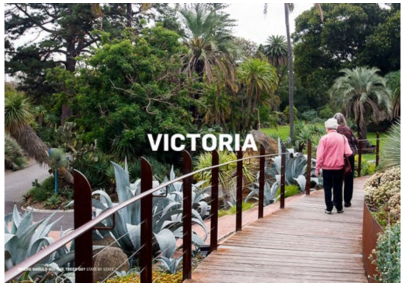
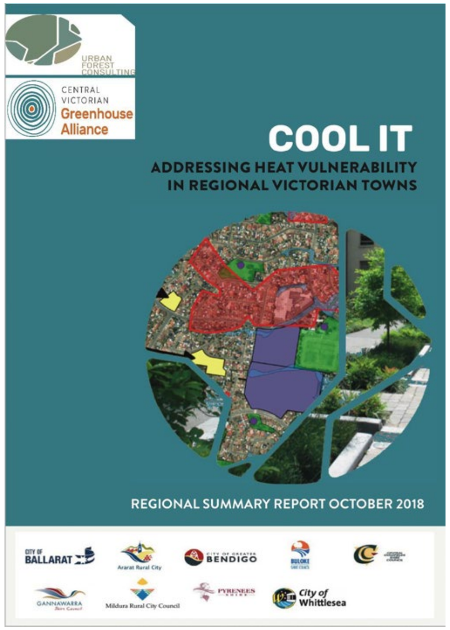
27. Where Should All The Treees Go? State buy State – Victoria University of Western Australia, 2017	

What	A state-specific analytical over-view on canopy loss, communities vulnerable to heat related stresses and potential for future canopy tree planting.
Findings	1. Average canopy cover for urban Vic is 18.83%, down 2.06% from 20.89% in 2013. (202020 Vision 2017, P2) 2. There has been an overall increase of 3%in hard surfaces, which is exactly the same rate of increase as NSW, but overall VIC has around 5% less hard surfaces than NSW. (202020 Vision 2017, P2) 3. In VIC, 44% of urban LGAs have undergone a significant loss of tree canopy, with only 8% having had a significant increase in shrubbery. (202020 Vision 2017, P2) 4. The report graphically represents LGA’s at higher risk, and highlights those LGA’s as areas where urban cooling strategies, and tree planting, need to be prioritized. 5. The report graphically represents the loss or gain of canopy and shrub cover over each LGA, and rates the losses on levels of severity. 6. The report defines trees as: “Anything that looks like a tree from above, distinguished from shrubs by the shadows cast.” 7. Shrubs are defined as: “Landscaped vegetation as well as bushland shrubs, crops and grapevines.” 8. Grass is defined as: “Cleared road sides, lawns, pastures, sites cleared for development and sporting grounds.” 9. Hard Surfaces are defined as: “Asphalt, buildings, car parks, footpaths, sandy beaches, train lines, rocky coastlines and water.” (202020 Vision 2017, P4) 10. The report defines Urban Heat Island Effect as: “An urban heat island is an area that heats up more than – and stays hotter than – its surrounding areas due to human impact of hard surfaces and development. Colours are used below to differentiate intensity of urban heat islands.” (202020 Vision 2017, P5) 11. The report cartographically represents a range of the hottest areas in Victoria, ranging from the hottest 16%, 8%, 2.5% 12. “Contiguous areas of urban heat spots or islands show a phenomenon more akin to an urban heat continent than a spot or island.” This observation has been represented graphically on page 6 of the report.
Proposed Strategies	- The report collates comments from different LGA government representatives, with Maroonda City Council stating: *“We realise that this is a broad brush analysis, but observe that the areas identified as greening opportunities due to the high temperatures are mostly intensively developed industrial areas, shopping centre car parks and the like. In terms of public greening, our current opportunities are limited to areas that council has control of, such as nature strips. Although it may seem challenging, the real opportunity is for there to*

	be more green infrastructure such as green roofs and walls within private locations, which we would encourage." (202020 Vision 2017, P13) - The report also identifies areas of greatest vulnerability and states that these areas have the potential to be prioritised for revegetation or urban cooling strategies.
References	Nil.

28. Cool It. Addressing Heat Vulnerability in Regional Victorian Towns Regional Summary Report October 2018 Central Victorian Greenhouse Alliance, Urban Forest Consulting 2018.	

What	The Cool It project is a collaborative council project coordinated through the Central Victorian Greenhouse Alliance. Objectives of the project are to: 1. Provide evidence and background information to inform better decision making for landscape based cooling solutions at each of the nine Councils . 2. Provide a proof of concept for a simplified methodology that utilizes existing and publicly available data to determine areas where social vulnerability and heat exposure overlap that other Councils can also implement without the need to acquire expensive thermal imagery or other datasets. The Cool it project used existing spatial data to determine urban areas of 9 Victorian regional and rural Councils that were socially vulnerable to heat impacts. 2016 Census data, Victorian Government data, open data and aerial imagery were used to i) identify parcels of urban areas where populations are most vulnerable to urban heat and heatwaves, and ii) prioritise those parcels of urban areas that are also exposed to more heat due to a combination of high pedestrian activity and hot urban surfaces. This methodology has been descrived in a document entitled "Cool It Project Mapping Methedology" for further reference. The identified heat vulnerable parcels have each been scrutinised further, with knowledge of each Councils strategic and policy position, to recommend specific streets and parks for cooling measures such as tree planting and/or irrigation as well as strengthening existing policy and strategy. (Urban Forest Consulting, 2018, P.3)

Findings	"Medical research shows that those over the age of 65 are one of the largest demographics impacted by heat. Other groups include young children, socio-economically disadvantaged people, older people living alone, those who aren't fluent in English, and disabled people. Loughnan et al., 2013). Therefore, the way we plan, renew, and build our towns and cities is of upmost importance in protecting these people from the impacts of heat. Imperviousness and urban heat are highly correlated (Coseo and Larsen, 2014). Unshaded asphalt and concrete are much hotter than green leafy parks or treed streets. But also, an unirrigated park with little shade provides very little relief from heat." (Urban Forest Consulting, 2018, P.4) "vegetation is far more effective at cooling if it has access to adequate water. Trees with large, healthy canopies shade a greater area but also act as water pumps, lowering the surrounding air temperatures through evaporative cooling. Investing in improving soil moisture levels in combination with increasing vegetation cover is therefore one of the most effective mechanisms to mitigate heat that local communities are exposed to." (Urban Forest Consulting, 2018, P.4) **Mapping Results** "*Social Vulnerability:* Each Council had slight but unique differences within the variability and presence of certain indicators for social vulnerability. Generally, the more urban or densely populated an area, the higher the diversity of social vulnerability indicators." (Urban Forest Consulting, 2018, P.7) *"Pedestrian Intensity:* Given the datasets were not uniform across each Municipality, there were no identifiable themes across the region in relation to pedestrian intensity." (Urban Forest Consulting, 2018, P.7) *"Impervious and Tree Canopy Cover:* Of more relevance for comparison, were the tree canopy cover statistics. 9 parcels out of the 54 point sampled, recorded tree canopy cover over 20%. These were in Heathcote and Kangaroo Flat (both in Bendigo), Avoca (Pyrenees), Charlton (Buloke), Cohuna (Gannawarra) and Mildura North. Whittlesea, Buloke, Ararat and Central Goldfields have exceedingly low tree canopy cover levels across all of their priority areas, some as low as 3%. "(Urban Forest Consulting, 2018, P.7) **Strategy, Policy and Program Gap Analysis Results** *Strategy* "Ballarat and Whittlesea both had good examples of overarching documents that were strong in this area. Ballarat 2040 and Greening Ballarat: A green blue action plan as well as Climate Ready Whittlesea are strong examples of integrated and evidence based strategy. "(Urban Forest Consulting, 2018, P.8) "Be Cool in Gannawarra is an excellent first stage educational campaign about the understanding the impacts of heat. http://www.gannawarra.vic.gov.au/News-Media/Be-Cool-in-Gannawarra" (Urban Forest Consulting, 2018, P.8) *Tree Strategies:*

	"Developing a Tree Strategy (or similar) was the most common desired outcome of using the results from the Cool It project, particularly at an implementation level. Converting these results into programs was the most commonly identified "next step" from this project. Of particular interest was the need to build business cases for increased tree program funding and to further prioritise where to direct constrained tree planting budgets." (Urban Forest Consulting, 2018, P.8) *Capacity Building:* "Regardless of the size of Council, all talked about the inability to convert high level visionary thinking down to on-ground works, particularly in relation to infrastructure works. There is a clear opportunity for capacity building within regional and rural Councils to raise awareness about the impacts of infrastructure on urban heat and the responsibility of good integrated decision making to mitigate these impacts. Ideally, infrastructure planning would be integrated to include consideration of urban vegetation, urban water/stormwater, heat and health and wellbeing." (Urban Forest Consulting, 2018, P.10)
Proposed Strategies	1. "Hold a Council forum to present the results of the Cool It Project and how Councils can utilise various recommendations within their own policy and operational frameworks. This would have the benefit of sharing information, recognising other pieces of work going on around the region and forming collaborations. Examples of documents that could be shared with Partner Councils to help guide some of their work: • Shepparton Development Guidelines • SDAPP Suite of tools Bendigo • Whittlesea Climate Adaptation • Ballarat Green Blue Action Plan • Bendigo's Vision for a Water Sensitive • City of Greater Bendigo's Tree Policy and Whittlesea's Street Tree Management Plan • Hindmarsh Shire Council Street and Reserve Tree Strategy" (Urban Forest Consulting, 2018, P.11) 2. "Establish a Cool It Working Group that includes relevant staff from across Council (e.g. arborist, urban designer, infrastructure design, infrastructure maintenance, communications, community development, etc.) with the aim of creating cross division linkages to enhance cooling outcomes in project delivery." (Urban Forest Consulting, 2018, P.11) 3. "Encourage all participant Councils to publish Cool It project results on their websites and include a page with information on what the community can do in their own backyards to increase cooling." (Urban Forest Consulting, 2018, P.11) 4. "Utilise the Cool It Working Group or Greening Regional Victoria group (as appropriate) to facilitate a forum or workshop with other institutional landholders across North and Central Victoria to discuss the Cool It project and what it means for them. Example landholders and service providers include VicRoads, Department of Health, DELWP, Department of Human Services, Bendigo Health, Ballarat Health, Regional Projects Victoria, Coliban Water, and Central Highlands Water." (Urban Forest Consulting, 2018, P.12)

	5. "Advocate for small changes to Health and Wellbeing State Government Act relevant to North and Central Victoria where heat impacts are larger than metro Melbourne. Impacts of climate change in central and northern Victoria must take into account the consequences of increased heat, not just heatwaves, coupled with the urban heat island effect in towns and cities. Overall tree canopy cover in many of these towns and cities is not high, posing a significant problem for cooling." (Urban Forest Consulting, 2018, P.12) 6. "seek to expand the remit of Heat Health Plans across North and Central Victoria so as to include proactive measures for heat mitigation and adaptation, not just reactive. Consider advocating for change within the State Government guidelines so that the Plans can be tied back to proactive, preventative actions that Council can deliver through existing programs i.e. trees, water, HACC programs, education etc. The Plans should also broaden the terminology around heat i.e. not just about heatwaves" (Urban Forest Consulting, 2018, P.12) 7. "Heat impact statistics: seek to replicate the health data collection conducted by City of Greater Bendigo with Bendigo Health to extract key heat health and wellbeing impacts such as admissions to hospitals and mortality." (Urban Forest Consulting, 2018, P.13)
References	1. City of Ballarat, 2016. Greening Ballarat: A green blue city action plan. http://www.ballarat.vic.gov.au/media/4090622/greeningballaratactionplan.pdf 2. City of Greater Bendigo, 2017. Urban Tree Management Policy. https://www.bendigo.vic.gov.au/sites/default/files/201708/Urban%20Tree%20Management%20Policy.pdf 3. City of Greater Shepparton, 2017. Landscape Plan Guide for developments in Campaspe Shire Council, City of Greater Shepparton and Moira Shire Council. http://greatershepparton.com.au/assets/files/documents/planning/Landscape_Plan_Guide_for_Council_Adoption_-_Web.pdf 4. City of Whittlesea, 2017. Climate Ready Whittlesea: Climate Change Adaptation Plan. https://www.whittlesea.vic.gov.au/media/3542/climate-ready-whittlesea-final.pdf 5. City of Whittlesea, 2016. Street Tree Management Plan. https://www.whittlesea.vic.gov.au/waste-environment/trees-and-plants/street-tree-management-plan/ 6. Coseo, P. and Larsen, L., 2014. How factors of land use/land cover, building configuration and adjacent heat sources and sinks explain Urban Heat Islands in Chicago. Landscape and Urban Planning, 125, p117-129. doi:10.1016/j.landurbplan.2014.02.019 7. Coutts.A. Tapper.N, 2017. Trees for a Cool CityGuidelines for optimized tree placement. Melbourne. https://watersensitivecities.org.au/wp-content/uploads/2017/11/Trees-for-a-cool-city_Guidelines-for-optimised-tree-placement.pdf 8. CRC for Water Sensitive Cities, 2018. http://www.watersensitivebendigo.org/project.html 9. Grey, V., Livesley, S.J., Fletcher, T.D., Szota, C., 2018. Establishing street trees in stormwater control measures can double tree growth when extended waterlogging is avoided. Landsc. Urban Plan. 178, 122–129. https://www.sciencedirect.com/science/article/pii/S0169204618304420 10. Hindmarsh Shire Council, 2018. Draft Street and Reserve Tree Strategy. http://www.hindmarsh.vic.gov.au/content/images/PDF%20forms/Infrastructure/Hindmarsh%20Street%20and%20Reserve%20Strategyv3%20July%2018.pdf 11. Hughes, L., Hanna, E. and Fenwick, J., 2016. The Silent Killer: Climate Change and the health impacts of extreme heat. Climate Council of Australia, http://www.climatecouncil.org.au/uploads/b6cd8665c633434e8d02910eee3ca87c.pdf

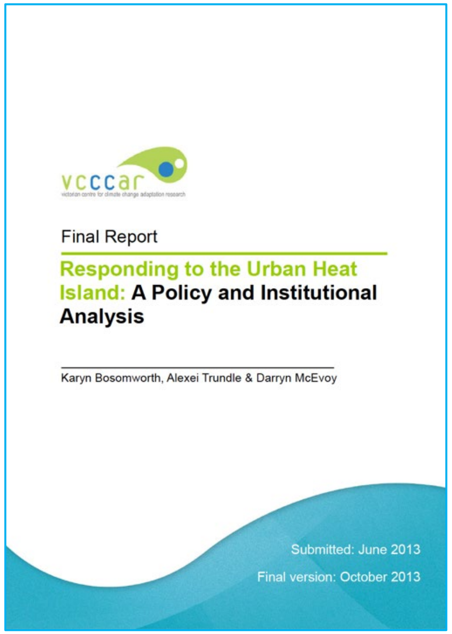
	12. IPCC, 2012: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp 13. Loughnan, M., Tapper, N.J., Phan, T., Lynch, K., McInnes, J., 2013. A spatial vulnerability analysis of urban populations during extreme heat events in Australian capital cities, National Climate Change Adaptation Research Facility. 14. Victorian State Government, 2018. Heat Stress and Older People, Better Health Channel, https://www.betterhealth.vic.gov.au/health/healthyliving/heat-stress-and-older-people#

31. Responding to the Urban Heat Island: A policy and institutional Analysis

K. Bosomworth, A. Trundle, D. McEvoy

2013

Victorian Centre for Climate Change Adaptation Research VCCCAR



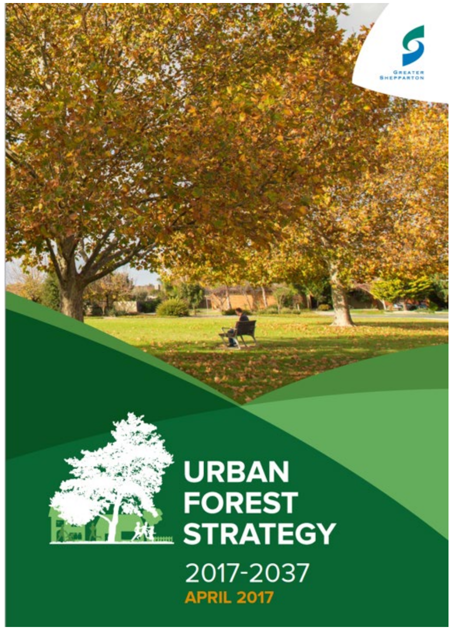
What	"This report contributes to a broader research project funded by the Victorian Centre for Climate Change Adaptation research (VCCCAR) that aimed to develop a better understanding of Melbourne's Urban Heat Island (UHI); to assess the effectiveness of different 'Green Infrastructure' (GI) systems in minimising heat accumulation and optimising cooling; and to develop a systematic approach for urban land managers to optimise the selection and implementation of different related GI adaptation options. Alongside these practical challenges are important institutional factors – perceptual, cultural, and political – that influence whether and how implementation of GI may or may not occur. Whilst there are differing definitions for GI in both the literature and in practice, for the purposes of this project, it is defined as: ***… the network of designed and natural vegetation found in our cities and towns, including public parks, recreation areas, remnant vegetation, residential gardens, street trees, community gardens, and innovative and emerging new urban greening technologies such as green roofs and green walls.*** This project report focuses on the institutional barriers and opportunities (in both policy and practice) that either inhibit or enable strategic implementation of GI as a means of addressing the UHI effect in the greater metropolitan region of Melbourne, Australia. It draws from three research activities: a review of the relevant literature; tabulation of policies that influence or have the potential to influence implementation of GI in Victoria; and semi-structured interviews with government personnel and other key stakeholders. Conclusions drawn from this analysis highlight a number of policy opportunities for Federal, State and Local governments that could enable improved implementation of GI in our urban landscapes. The findings have also contributed to the development of the project 'Green Infrastructure Implementation Guide' (GIIG) for local governments (Norton *et al.* 2013). (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.8)

Findings	1. “Findings regarding definitional differences regarding UHI suggest that policies will have to be flexible enough to address the complexities of urban heat at differing scales, ranging from surface temperature in an allotment or streetscape, through to differences in day and night time heat profiles across the metropolitan area.” (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.14) 2. “This project defined GI as “the network of designed and natural vegetation found in our cities and towns, including public parks, recreation areas, remnant vegetation, residential gardens, street trees, community gardens, and innovative and emerging new urban greening technologies such as green roofs and green walls” (Melbourne University, GI Research Group). 3. “*Water conservation* Most interviewees linked green with blue infrastructure; particularly water conservation and Water Sensitive Urban Design (WSUD) projects. Respondents suggested that this focus, in the Melbourne context, has been driven by the dominance of water conservation strategies during the decade-long drought and associated State and Federal Government policies. The association with WSUD emphasises the need for a multi-objective approach to GI implementation. One example that was noted was that the integration of WSUD into hard or existing open spaces allows use of stormwater rather than potable water for GI maintenance; as well as pollutant runoff management, improved water filtration, reduced impacts of initial storm flows and subsequent urban flooding.” (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.20) 4. “it is worth noting that a number of respondents mentioned that certain water conservation measures and policies in the past had also led to reductions in GI at local and household scales, where ‘green spaces’ were replaced with artificial turf and hard surfaces to address water restrictions.” (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.20) 5. “*Reduced costs of ‘hard’ infrastructure* For a number of participants an equally if not more important role for GI was to reach beyond the support of WSUD and to reduce the need for costly ‘hard’ infrastructure such as pipes and stormwater drainage; as well as improving economic efficiencies, productivity, and costs of drainage management.” (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.20) 6. “*Natural hazard impact reduction* A few interviewees suggested that certain forms of GI could also reduce the consequences of natural hazards beyond heatwaves. One respondent suggested that because tree canopies slow rainfall impact and tree-trunks direct water into permeable soils, potential storm impacts are secondarily reduced. Because of potential lessening of natural hazard impacts, one respondent argued that GI can also help reduce the ‘down time’ of damaged infrastructure and thereby recovery costs following extreme weather events. These observations also reflect one of the dominant drivers behind WSUD, which is frequently justified on the basis of reduced storm-water flow.” (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.20) 7. “*Sense of connection to environment* An increased appeal of urban public spaces was argued to be a key enabler of public acceptance and appreciation of GI, and conversely, a co-benefit. One interviewee suggested that local stakeholder involvement in the design, establishment and maintenance of local GI enables individuals to express their concerns for the environment and/or climate change in their local area. This kind of active community involvement was described as both empowering and rewarding. Such insights are salutary for any efforts toward increased establishment of GI across the Melbourne conurbation.” (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.20) 8. “*Contribution to an areas Liveability* The role of GI in enhancing an area’s ‘liveability’ was identified as the strongest community-level benefit from a local government perspective. Useable and accessible GI was seen as fundamental to community support for and ‘ownership’ of public open space, particularly with respect to community members being able to exercise and relax in such spaces. However, the degree of this co-benefit was argued to be dependent upon both scale and location; smaller open space restricts activity and capacity to relax, while the scarcity of open space in higher-density areas heightens its value in certain localities. Such considerations also parallel findings in the literature regarding the importance of network design in its contribution to UHI reduction.” (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.21) 9. “*Building energy efficiency*

	While interviewees were unable to identify information or data to quantify the role of GI in reducing energy demand, there was a general sense from the participants that there is potential for both energy savings and improved energy efficiency through the shading and insulation of buildings. This is consistent with observations in the literature; for example a study in Auburn, Alabama, USA, estimated that every 10% increase in shade cover would reduce electricity consumption by 1.29Kw/day for a 'typical' house (Pandit & Laband 2010). A key issue in this argument is that such benefits are individual rather than social." (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.21) 10. "Policies and strategies aimed at streetscapes, open spaces, sustainable urban design, and WSUD, are considered to be ideal vehicles for an increased uptake of GI, as they support the notion of 'co-benefits'. Moreover, the imperative to reduce the UHI provides an additional argument in any business case for these existing policies, strategies, and programs. All participants indicated that their council had some form of policy and/or strategy aimed at (or that could incorporate) increased greening of the municipality. The research suggested that Water Sensitive Urban Design (WSUD) or stormwater management appear to be the primary drivers for GI and related open spaces in the Melbourne context." (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.21) 11. Provision of Public (and Private) Good. "there is somewhat of a divide between those who implement or fund GI projects and those who stand to benefit. Benefits were generally described as being divided between the public at large – where establishment of GI reduces ambient temperature in public open space and streetscapes improving broad thermal comfort - and those available to individual landholders or building occupants – where GI provides insulation for individual buildings, benefiting energy efficiency, and reducing energy costs. This differentiation, more than the nature of the benefits themselves, appeared to be a key factor in determining the extent and type of GI implementation. Interviewees suggested that those projects perceived to share the benefits across multiple stakeholders appeared to have greater chances of implementation." (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.22) 12. "Local government participants generally argued that most municipalities focus on public spaces because the ability and capacity of councils to modify privately-owned land is limited. However, a handful of respondents discussed the importance of community engagement in addressing this challenge, including the role of urban agriculture and 'home-grown' food or 'smart garden' programs. Certainly, projects such as 'Greening the West' (a partnership between City West Water and a number of western Melbourne industry and local government partners) are aimed directly at collaborating with private landholders to achieve a more landscape-wide effect." (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.23) 13. Implementation Barriers include: 13.1. *Lack of technical guidance* Several participants argued that while there is a large amount of information about differing aspects of GI, it is not consolidated enough to provide sound and reliable guidance to planners and other relevant policy practitioners. This is a gap at which the project GIIG was aimed. [Moreover, this small but significant finding suggests that the GIIG should not attempt to provide guidance on every single aspect of GI, but rather be a roadmap, portal, or central point of reference through which detailed information can be sought from pre-existing information and guides. (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.24) 13.2 *Costs* "Every interviewee raised the issue of costs associated with establishment and maintenance of GI. In short, the more complex and innovative, the more costly. Most interviewees guessed that street trees would be the cheapest GI option and green walls the most expensive, high-maintenance option on a coverage basis – an assertion consistent with empirical assessments in the international literature (see for example, EPA 2007). While GI such as street trees and rain-gardens were seen as achieving multiple outcomes, several interviewees described costs, time, and expertise as particularly prohibitive to the implementation and maintenance of green walls and roofs." (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.24) 13.3 *Spatial variability of urban heat and land use change* "Several interviewees from western councils highlighted that this distinctive GI distribution was due to variation in average annual rainfall across the city (Figure 7), and thereby the city's western native vegetation tends to be of the sparser, drier systems such as those occurring

	in the bioregion known as the Victorian Volcanic Plains (DSE 2007). A consequence of these (drier) landscape characteristics is that some western municipalities struggle to keep street trees alive, particularly during periods of low rainfall. State-level policy would need to recognise these concerns in order to engage western municipalities, and avoid framing the UHI effect as an inner city, high urban density, issue." (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.25) 13.4 *Local Government Capacity and Resources* "Directly related to the costs of establishing and maintaining GI was the broader issue of varying financial and resource (human, infrastructure, skills) capacity among Victoria's local governments. An example of variation in financial capacity across urban councils is that the smallest council has an annual budget of $6 million per annum while the budget of the largest is $312 million (VCEC 2010). Similarly in 2008-09, the Borough of Queenscliff employed 44 staff, while the City of Melbourne employed 1211 people (Borough of Queenscliff, 2010:30; City of Melbourne 2009:12). One respondent stated that because their council has limited funds they are unable to explore a range of GI options," (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.27) "one respondent in this study argued that currently available grants are short-lived and lack long-term strategic vision. Moreover, while such grants may support initial establishment, they do not adequately account for the long-term maintenance programs required for GI (a situation likely exacerbated by the absence of a long-term strategy or program). These findings suggest that a valuable policy support mechanism would be recurrent, strategic, funding for GI that meets individual local requirements." (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.27) 13.4 *Land Ownership* "greater implementation of GI to address UHI through management of local council-owned land alone is unlikely to achieve a city or municipality-wide reduction in (or avoidance of an enhanced) UHI. In large part, this is due to local councils having limited ownership or direct control over the management of land….reliance on council-controlled open space as the primary mechanism to address UHI would not produce optimal outcomes." (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.28) "At the same time, the amount of GI on private properties appears to be shrinking (DSE 2011). …. which indicates that "in growth areas where the largest proportion of Melbourne's new housing is being constructed, lot sizes are becoming smaller while house sizes are increasing" (Goodman *et al* 2010). In this context, addressing UHI (created by growing urbanisation) through GI is limited where little room remains for any vegetation on individual private properties….regulation and incentives for GI on privately-owned land will need to be considered, alongside co-ordination with state-level utilities and other government agencies. (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.28) 13.5 *Whole of Government Approach* "Many respondents suggested that while they are aware of a myriad of information and data, it is not provided or available in any consolidated manner that acts as a useful guide for development of local GI policies. Many also suggested that there is a distinct lack of clarity in the overarching policy context and a more coherent, coordinated or regional approach between the different municipalities is needed." (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.29) "interviewees consistently made the point that perceptions of the value, purpose and management of GI among different groups of people was an important influence both on policy development and very often on GI establishment and maintenance. For example, 'engineering' departments were consistently described as being concerned about the potential for the root systems of street trees to wreck roads, footpaths, and pipe infrastructure for water, gas and electricity. (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.30) "while an Open Space Policy provides councils a key mechanism for being directly involved in decisions surrounding the approval and implementation of such developments, ultimately broader State Government has greater influence over the design, approval and implementation of large urban areas such as neighbourhood or precinct scales. As discussed earlier, the challenge of such interacting policy (and decision) scales is that UHI 'hotspots' may not occur on lands whose development and management councils can directly modify or influence. This is irrespective of the vulnerability of these locations to heatwaves or the UHI (such as old-persons homes, disadvantaged areas, childcare facilities etc)" (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.30)

	13.6 *Land use planning and development* “four municipalities recently submitted “Amendment C117 Local Planning Policy – Stormwater Management (Water Sensitive Urban Design)”, a local planning policy proposal, to the Minister for Planning. According to the City of Port Phillip’s website, the policy aims to “encourage new developments to incorporate the use of best practice stormwater treatment measures (water sensitive urban design) in their planning applications”. A number of GI-related WSUD options are among potential measures identified within the proposed policy as components of vegetated swales and buffer strips, rain gardens, wetlands and suspended growth biological processes. (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.31) **Zoning** “One industry representative explained that green roofs and vertical gardens are currently marketed towards medium to high-density developments because these urban forms better distribute installation and maintenance costs. This cost-sharing approach, coupled with increased demand for (and reduced supply of) GI in built-up areas, presents a potential opportunity for both policy focus and industry-engagement, albeit driven by individual or organisational GI co-benefits rather than the predominantly social goods derived from reduced surface temperature…..Integration of commercial and industrial developments through ‘mixed-use’ zoning was also seen as providing conditions that are amenable to the incentivisation of vertical and roof-based green infrastructure, with the marketing and aesthetic benefits being perceived as having immediate returns for business; in contrast to the delayed re-sale benefits derived from a residential property. In some instances these desirable marketable qualities may even outweigh the social goods themselves, with interior vertical gardens requiring high-energy lighting installations to ensure their survival, resulting in a positive net heat output and associated energy-based emissions. Such examples provide further evidence for the need for an improved whole-of-system understanding of the effectiveness of GI types and plant species in reducing local temperature, in order to prevent instances of maladaptation.” (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.31) **Growth boundaries & densification** “Greenfield sites present different opportunities for GI implementation compared with those of re-development or retro-fit sites within existing suburbs. In particular, growth area council representatives argued they were limited in resources (as rates were yet to be paid by incoming constituents), decision-making power (much of which lies with the State planning minister and the Growth Areas Authority in these designated areas) and planning timeframes (driven by land release pressures). The literature reinforces this, identifying the demands of housing affordability and development speed as reducing the capacity to innovate, while shrinking lot sizes equally reduce the capacity for establishment of privately owned green cover (DSE 2011; VEAC 2011).” (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.32) “***Potential role for the Growth Areas Authority (GAA)*** There are a number of regulatory and planning areas where the Growth Areas Authority (GAA) could play a more active role in enabling GI in greenfields precinct planning, specifically targeting the day-time UHI impacts that are prevalent in Melbourne’s growth areas. For example, the current GAA Engineering Design and Construction Manual (GAA 2011) does not explicitly consider issues such as permeable pavements, high thermal emittance surface materials, and sustainable product sourcing. Similarly, the Authority’s Precinct Structure Planning Guidelines only prompt *consideration* of appropriate design responses for addressing heatwaves, while Open Space requirements do not require consideration of climate change adaptation (GAA 2011 p 25). (K. Bosomworth, A. Trundle, D. McEvoy, 2013, P.33) -NOTE: report continues – after discussion with team it is believed that reviews of such information is not relevant to our scope of work.
Proposed Strategies	-
References	-

32. Greater Shepparton City Council Urban Forest Strategy 2017-2037 April 2017 Greater Shepparton Council + Urban Forest Consultancy + Tree Logic Pty Ltd	

What	"This Urban Forest Strategy has been developed to set a vision, objectives, targets and a series of actions for Council to adopt and adhere to over the coming decades. It will provide the strategic framework for existing tree management policies, technical guidelines and precinct plans and links in with Council's existing strategic priorities such as community health and wellbeing, liveability, climate change and place making." (Greater Shepparton Council, Urban Forest Consultancy, Tree Logic 2017 P.3)
Findings	Maintaining and improving upon Urban Forest has three key areas of benefit: 1. Health and Wellbeing: - Shade trees reduce daytime temperatures between 5 – 20 degrees. - Encourages people to spend time outdoors and interact with their community, particularly in areas of socio-economic disadvantage. - Improves amenity and aesthetics of public open space, particularly playgrounds, encouraging active play. -Encourages motorists to drive more slowly through provision of uniform, avenue-like plantings along streets. - Reduces air, water and soil pollution (Greater Shepparton Council, Urban Forest Consultancy, Tree Logic 2017 P.9) 2. Economic: - Shoppers spend longer and more money in shopping areas that are well treed and landscaped. Trees can improve retail activity by 20%. - Increases house prices in Brisbane and Perth through the provision of healthy and well maintained street trees. - Reduces energy usage in buildings. A 10% increase in deciduous tree cover can reduce heating and cooling costs in houses by 5-10%. - Improves the brand/ character and amenity of a region.

	- Can provide a return on capital of up to 5 times (eg. New York's street trees return $5 for every $1 invested). (Greater Shepparton Council, Urban Forest Consultancy, Tree Logic 2017 P.9) - One of the most cost effective and efficient public assets for adapting urban areas to climate change through provision of shade, evapotranspiration and stormwater interception. (Greater Shepparton Council, Urban Forest Consultancy, Tree Logic 2017 P.10) 3. Environmental: - Significantly reduces stormwater flows and improves stormwater quality. - Connects biodiverse locations by creating a green corridor. - One of the most effective mechanisms for reducing the Urban Heat Island Effect. (Greater Shepparton Council, Urban Forest Consultancy, Tree Logic 2017 P.9)
Proposed Strategies	Develop a long term plan with actions that fall under the Planning, Operational, Community Collaboration and Developer Sectors: **1. Planning:** 1.1 Identify all potential streets as habitat corridors to link areas of ecological value. 1.2 Identify all pedestrian and cycle paths as part of the Movement and Place Strategy that should be prioritized for tree planting in conjunction with the planning team. 1.3 Develop an equitable 10 year street and park tree planting program targeting areas of need. 1.4 As part of the CBD Activation Strategy and Revitalisation Project develop a CBD specific tree planting and renewal program. 1.5 Develop tree design guidelines for the CBD including structural soils and cells, water sensitive urban design and soil health. 1.6 Develop a planned and proactive tree renewal program based on audit data. 1.7 Review and update existing Precinct Plans and preferred species list as part of 10 year street tree planting. 1.8 Update Council's tree management guidelines to reflect best practice and latest research including design guidelines for passive irrigation of trees from stormwater. 1.9 Continue to integrate water sensitive urban design with design of all tree plots. 1.10 Tree protection on private property: local laws. 1.11 Attribute a dollar value to Council owned urban trees, include in asset management system. 1.12 Align with the future Greening Shepparton Strategy, and future iterations of Council Plan. 1.13 Investigate greater private tree protection measures. Review local laws regarding private trees to ascertain best possible protection. 1.14 Investigate the use of dollar bonds to protect trees during construction works. **2. Operational:** 2.1 Work with all relevant internal Council teams to collaborate and provide input into all streetscape operational programs. 2.2 Update the Infrastructure Design Manual to include appropriate typologies for tree growth. 2.3 Support innovation in streetscape materials selection and design to accommodate larger trees in the landscape. 2.4 Increase the size of tree species used in streets to achieve greater service benefits, such as shading. Aim for an increase in 10-12 m tall tree species (medium size). 2.5 Reduce Callistemon spp. numbers and manage the ongoing planting of Pyrus carefully. 2.6 Continue to prioritise the maintenance and protection of the existing tree population in order to maximise the benefits already received from this asset. 2.7 Provide training and workshops to build internal capacity for innovation around best practice streetscape design e.g. tree pits, structural cells, wsud, median street tree planting etc 2.8 Continue to maintain a dynamic inventory of the tree asset that will provide up-to date tree status information. Update the inventory every five years. **3. Community + Collaboration:**

	3.1 Engage with and educate the community on the benefits of trees, their management requirements and Council's role in managing them. Council will continue to raise awareness of the value and need to protect, enhance, expand and restore the urban forest. 3.2 Develop a series of annual events to encourage the community to consider their perceptions of the urban forest e.g. design and story competitions, "ask the arborist sessions", workshops on planting trees, species selection for a natural environment. 3.3 Engage with schools to discuss the role that children can play in the planning, design and management of the urban forest. 3.4 Update the urban forest webpage on Council's website. 3.5 Run engagement sessions in each town to discuss their desired neighborhood characters and how the 10 year tree planting plan will influence them. 3.6 Continue running National Tree Planting days. 3.7 Work together with RiverConnect to improve biodiversity links from the river to suburban streets. 3.8 Work alongside Powercor and Goulburn Valley Water to ensure their programs of works support urban forest outcomes. 3.9 Continue to work closely with Powercor around powerline clearance requirements. 3.10 Work together with VicRoads to plant boulevards and gateway entries in each town of Greater Shepparton. 3.11 Work together with DELWP's Good Neighbour program to encourage community members to take care of and advocate for the urban forest. 3.12 Encourage the community to plant more trees on their own private land. 3.13 Work together with the One Child One Tree program to help plant trees in areas of need. **4. Developers** 4.1 Preferred tree species lists to be given to all Developers at planning stage. 4.2 During planning approval for all new developments, plans for all pieces of infrastructure e.g. footpaths, roads, underground services and trees are to be considered together to ensure there conflicts are minimised. 4.3 Implement an updates Street Works Code of Practice that includes tree planting requirements in best practice streetscape typologies. 4.4 Site handovers to Council are to be audited and if tree quality and quantity does not match plans, developer must replant or pay a fee for Council to complete the work.
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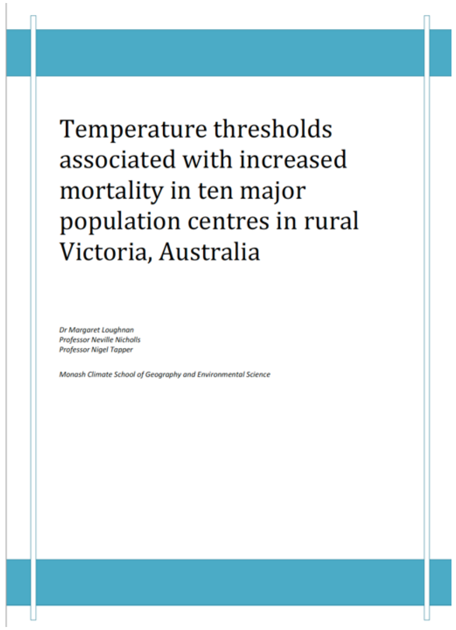
33. Temperature thresholds associated with increased mortality in ten major population centres in rural Victoria, Australia

Dr Margaret Loughnan
Professor Neville Nicholls
Professor Nigel Tapper

2006

Monash Climate School of Geography and Environmental Science


Temperature thresholds associated with increased mortality in ten major population centres in rural Victoria, Australia

Dr Margaret Loughnan
Professor Neville Nicholls
Professor Nigel Tapper

Monash Climate School of Geography and Environmental Science

What	"The research described here examines whether similar mortality-temperature thresholds to those found for Melbourne also apply to rural Victorian population centres. The Melbourne heat alert system is based on the identification of this mortality-temperature threshold 12 and relies on readily available temperature forecasts from the Bureau of Meteorology (BoM). If temperature thresholds, above which excess deaths occur, can be found for rural population centres, then daily weather forecasts could be used to develop an operational heat alert system for most population centres in the State." (Loughnan, Nicholls, Tapper, 2006, p. 3) Studies were undertaken on the following regions and centres: Bendigo, Wodonga, Latrobe Valley, Horsham, Westernport Region, Hamilton Region, Lakes Entrance, Geelong, Shepparton Region, Ballarat Region and Mildura Region.
Findings	1. Bendigo/ Loddon: - Marked increase in mortality when the mean temperature (9am-9am) is 32 degrees and above. - Days with temperatures above this threshold are associated with a median mortality increase of 18%. - It is recommended that a mean temperature of 32 degrees is used as the base for heat alerts for this region. 2. Wodonga: - There is no clearly identifiable increase in mortally for MeanT in this region. - There is a notable increase in mortality when the maximum temperature exceeds 40 degrees (20%) 3. Latrobe Valley/ Gippsland Region: - Marked increase in mortality when the mean temperature is above 30 degrees, and when minimum temperature exceeds 22-24 degrees and when the maximum temperature exceeds 36 degrees.

	- The minimum temperature threshold for Latrobe Valley of 22 degrees is associated with a 20 – 30% increase in mortality. - On days where mean and maximum temperature thresholds are exceeded there is a median mortality increase of 18%. 4. Horsham/ Grampians Region: - Mortality increases when the maximum temperature rises above 38 degrees and mean temperature exceeds 32 degrees. - A mean temperature threshold of 32 degrees results in a median mortality increase of 10%. - A similar increase in mortality is noted for days when the maximum temperature exceeds 38 degrees. 5. Westernport Region: - Both Melbourne and Latrobe Valley demonstrate an increase in mortality when the mean temperature is 30 degrees or above, this is most likely to be the case for the Westernport Region also. 6. Hamilton Region: - Mortality increases when the maximum temperature exceeds 42 degrees. - The effect of high minimum temperature of 24 degrees results in an increase in the mortality. - A mean temperature threshold of 34degrees results in an increase in mortality. - There is a small increase in mortality when the mean temperature is between 26 and 32 degrees. - A minimum temperature threshold of 24 degrees demonstrates a clear increase in mortality in the elderly. 7. Lakes Entrance: - Days with a max temperature of over 38 degrees are associated with increased mortality. - Min temperatures over 23 degrees are also associated with increased mortality. - Increased mortality is also noted for episodes when the mean temperature exceeds 30 degrees. - There is a mortality increase of 15% on days exceeding the temperature max threshold of 38 degrees. - A mean temperature threshold of 30 degrees is associated with a mortality increase of approximately 7%. 8. Geelong: - Data collected suggests that elderly residents in this region respond to the previous days maximum temperature. Effects may be related to the daytime UHI or late afternoon peaks in temperature. - On the day following a day when temperature exceeds the thresholds (max 38 degrees, mean of 28 degrees) the median mortality anomaly is between approximately 15 – 30%. - Authorities should be notified that mortality is likely to peak on the day following a day that exceeds the max temperature threshold. 9. Shepparton Region: - Mortality is substantially increased when maximum temperature exceeds 43 degrees, and when min temperature exceeds 26 degrees, and when mean temperature is between 30 and 32 degrees. 10. Ballarat Region: - Days when mean temperature exceeding 30 degrees show an 18% increase in median mortality. - There is a small but consistent increase in mortality when the minimum temperature threshold of 18 degrees is exceeded. 11. Mildura Region: - Maximum temperature shows a small increase in mortality when temperature exceeds 42 degrees. - The increase in mortality continues to rise when temperature exceeds 44 degrees and 46 degrees, exhibiting a clear increase in mortality with increased temperature. - Minimum temperature threshold demonstrates an increase in mortality at temperatures above 27 degrees. - There is an unexplained decrease in mortality in the elderly when temperatures are between 25 – 27 degrees. Decrease may

	represent the thermal tolerance or the level at which residents use air conditioners overnight. - Increased mortality at higher overnight temperatures of 27 and 29 degrees and over may show that air conditioners become ineffective at these thresholds. - There is a 10% increase in median mortality when the mean temperature threshold of 35 degrees is exceeded. - Increases in mortality are noted when minimum temperature exceeds 29 degrees and maximum temperature exceeds 44 degrees. 12. In all major Victorian rural population centres across Victoria hot weather exceeding a specific threshold results in an increase in mortality in persons aged 65 years and older. 13. Clearest thresholds are, in general, with a daily Mean temperature. 14. Calculating the average daily temperature from 9am one day to 9am the following day takes into consideration a hot day followed by a hot night. This lack of relief from the heat appears to result in increased mortality in the elderly. 15. The importance of this is highlighted by the number of older persons living in rural communities. 16. It appears that older people living in the more temperate eastern side of the state are more vulnerable to heat events than those living in the warmer western regions.
Proposed Strategies	1. The Victorian government should implement a Heatwave Plan for rural and regional centres, not just Melbourne. 2. Heat alert systems could be implemented using the Bureau of Meteorology forecasts.
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34. The urban heat island in Melbourne: drivers, spatial and temporal variability, and the vital role of storm water.

A. M. Coutts, J. Beringer, S. Jimi and N. J. Tapper 2015

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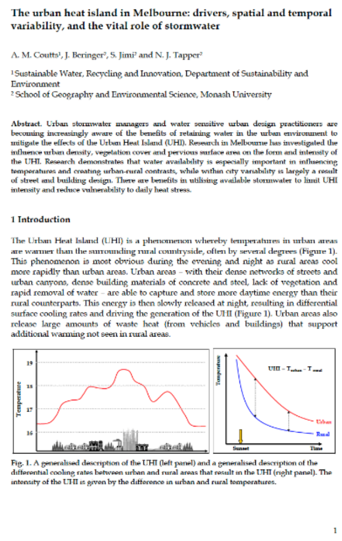

The urban heat island in Melbourne: drivers, spatial and temporal variability, and the vital role of stormwater

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Abstract. Urban stormwater managers and water sensitive urban design practitioners are becoming increasingly aware of the benefits of retaining water in the urban environment to mitigate the effects of the Urban Heat Island (UHI). Research in Melbourne has investigated the influence urban density, vegetation cover and pervious surface area on the form and intensity of the UHI. Research demonstrates that water availability is especially important in influencing temperatures and creating urban-rural contrasts, while within city variability is largely a result of street and building design. There are benefits in utilising available stormwater to limit UHI intensity and reduce vulnerability to daily heat stress.

1 Introduction

The Urban Heat Island (UHI) is a phenomenon whereby temperatures in urban areas are warmer than the surrounding rural countryside, often by several degrees (Figure 1). This phenomenon is most obvious during the evening and night as rural areas cool more rapidly than urban areas. Urban areas – with their dense networks of streets and urban canyons, dense building materials of concrete and steel, lack of vegetation and rapid removal of water – are able to capture and store more daytime energy than their rural counterparts. This energy is then slowly released at night, resulting in differential surface cooling rates and driving the generation of the UHI (Figure 1). Urban areas also release large amounts of waste heat (from vehicles and buildings) that support additional warming not seen in rural areas.

Fig. 1. A generalised description of the UHI (left panel) and a generalised description of the differential cooling rates between urban and rural areas that result in the UHI (right panel). The intensity of the UHI is given by the difference in urban and rural temperatures.

1

What	"This paper outlines research conducted in Melbourne aimed at demonstrating the temporal and spatial variability of the UHI across the city and identifying the specific drivers that cause this variability. In particular, research investigated whether the UHI increases with increasing urban density and the role of vegetation cover and pervious surface area (and other surface characteristics) on evapotranspiration and the UHI. Evapotranspiration is a particular focus as it is influenced by the amount of water in the urban environment – which is partly controlled by storm water management." (Coutts, Beringer, Jimi, Tapper, 2015 p. 2)
Findings	1. With increased water run-off (due to the natural landscape being replaced with hard, dry impervious surfaces). water infiltration is restricted, significantly reducing evaporation and natural environmental cooling. 2. With reduced water in the landscape, there is little water for trees and vegetation to draw upon to transpire into the atmosphere. In extremely hot and dry weather, the stomata of the leaves shut down in order to prevent moisture loss. Over time the leaves shrivel and die – which can also lead to the death of the whole tree. 3. This leads to very dry urban landscape and means more energy is partitioned into either heating the atmosphere or into heat storage (driving up night time UHI). 4. Effects of UHI are heightened in times of drought and water restrictions as no supplementary water supply is provided into the atmosphere either. 5. "No matter whether it was a built up site, or a more open and vegetated site

	– rates of evapotranspiration were low across the entire urban landscape. Because the pervious surface areas (particularly the grassed areas) were so dry, they effectively function in a similar manner to impervious surface areas – because the surface is hard and sheds water quickly and there is little sustained infiltration." (Coutts, Beringer, Jimi, Tapper, 2015 p. 4) 6. "under current urban layouts, once the natural landscape is replaced with even low density development, evapotranspiration is significantly reduced and increase the availability of energy for heat storage and atmospheric heating leading to a baseline increase in UHI intensity. Low rainfall or poorly irrigated areas are more susceptible to additional heat storage and atmospheric heating." (Coutts, Beringer, Jimi, Tapper, 2015 p. 5) 7. "UHI intensity is dominated by the balance between the ability of the landscape to absorb and retain heat and energy. The amount of heat adsorbed during the day and retained in the landscape is controlled by a complex combination of variables including: the 3D urban morphology; type of surface materials; albedo; impervious surface cover; and water availability." (Coutts, Beringer, Jimi, Tapper, 2015 p. 6) 8. "Mean radiant surface temperatures increase with increasing housing density." (Coutts, Beringer, Jimi, Tapper, 2015 p. 6) 9. "As the complexity of landscape increases with narrower, deeper urban canyons, the more difficult it is for heat to escape – keeping temperatures warm throughout the night and creating the differential cooling rates that produce the UHI." (Coutts, Beringer, Jimi, Tapper, 2015 p. 6) 10. "Vegetation can also play a role in limiting surface heating by shading buildings, roads and other impervious surfaces (Wong et al 2003), but in order to be effective, vegetation needs water." (Coutts, Beringer, Jimi, Tapper, 2015 p. 7) 11. "By increasing evapotranspiration in the urban environment, we can help reduce the amount of energy available for the heat storage and UHI generation." (Coutts, Beringer, Jimi, Tapper, 2015 p. 7)
Proposed Strategies	1. "There are a range of mitigation measures that are available to minimise the intensity of the night time UHI including: water sensitive urban design; increased vegetation and open space; high albedo and thermal emittence surfaces; street design (control height to width ratios) and energy efficiency." (Coutts, Beringer, Jimi, Tapper, 2015 p. 7) 2. "Evapotranspiration rates and surface temperatures are not simply aligned with vegetation cover but rather water availability. Therefore, increased vegetation cover to mitigate the UHI must be accompanied by water retention strategies in order enhance the effectiveness of vegetation." (Coutts, Beringer, Jimi, Tapper, 2015 p. 7) 3. "water retention strategies through water sensitive urban design, stormwater capture and reuse are particularly beneficial. While high albedos and changes in street design can limit heat storage – water retention strategies (especially those that support vegetation) can both limit heat storage (and limit UHI intensity) and encourage evapotranspiration." (Coutts, Beringer, Jimi, Tapper, 2015 p. 7) 4.
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