Asset Vulnerability Assessment Project

Stage 1 – First Pass Methods Report

Prepared for: South East Councils Climate Change Alliance (SECCCA)

Final

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1. This Document

This report presents the high-level vulnerability assessment approach to be applied to agreed council assets as part of the SECCCA Asset Vulnerability Assessment (AVA) project. This high-level assessment approach has been termed part one of a two-part vulnerability assessment and is viewed equivalent to what is generally termed a first pass assessment climate change study in that it comprises a high-level generic assessment based on an agreed set of asset attributes. This part one assessment will be applied on a SECCCA council wide basis.

A more detailed part two vulnerability assessment, or second pass assessment, will be undertaken in the form of case studies. These case studies will include a detailed review of anticipated costs in relation to specific climate related impacts, and an evaluation of adaptation and replacement options to reduce projected climate change costs.

2. Background

2.1. This Project

This project was aimed at assisting SECCCA member councils to better understand how their buildings, roads, drainage and open space will be impacted by climate change and associated extreme weather events.

More specifically, SECCCA notes that the project is aimed at assisting councils to understand:

- how will climate change impact a particular asset
- how might service delivery be impacted by climate change
- how much extra will an asset or service cost to maintain or deliver assuming no adaptation action
- how much extra can councils expect to pay to respond to damages or pay in insurance
- how much would be the expected cost of making assets resilient; and
- how might council income streams be impacted by climate change.

Through the case studies, the project identifies how related council income and expenditure will be impacted, and provide guidance on how councils can appropriately plan – financially and strategically - for the anticipated changes. By having a greater understanding of asset vulnerability and the potential financial impacts of climate change, councils can appropriately plan and cost work plans in order to make assets more resilient. In turn this will assist to improve understanding of how climate change is likely to impact the delivery of community services.

The project also helps councils understand the potential impact of climate change and associated extreme weather events on local communities. The project aligns with climate risk methodologies and standards such as the CMSI (Climate Measures Standards Initiative).

2.2. Understanding Likely Change

To better plan for likely climate change related impacts, council staff need to better understand the anticipated changes in the climate, and the associated flow on effects. This change in the climate can be expressed in terms of climatic variables, such as the number of days over 35°C per month, or in terms of sea level rise and likely area impacted by this and associated storm surge events.

Spatial views of where change is likely to occur, such as which areas are more likely to be flooded, or be subjected to a greater number of heatwaves, are required to identify the likely impact of the anticipated changes.

By utilising the most recent climate projections from CSIRO and DELWP, as well as region wide inundation and in-house flood modelling, the level of change across the SECCCA region can be identified. Critically this change needs to be defined relative to an appropriate baseline or reference period in time so that future exposure to change and associated impacts can be accurately identified.

Hence, a key first step in this project was the suitable collation and standardisation of data, including climate and climate projection data, and relevant council climate event or event modelling data.

2.3. Understanding likely Asset Impacts and Vulnerability

Vulnerability is a function of exposure to climate factors, sensitivity to change and capacity to adapt to that change. To suitably identify or model the likely vulnerability of a particular asset requires an understanding of how sensitive a particular asset is to different levels of change, and whether there are factors, such as condition, that increase or reduce the impact of the anticipated change.

It is important that key attributes of an asset that influence its sensitivity, such as the materials it is built from, the design standard under which it was built, or its age, are identified so that the likely impact of an identified level of exposure to change can be expressed in terms of the likely impact this change will have on an asset. These attributes essentially define an asset, and are generally unable to be changed.

In addition, there are factors about an asset that you can change, such as its maintenance level, or barriers built to protect an asset. These can be termed adaptation activities (or adaptive capacity factors). Bringing these together in a well-defined and consistently applied framework is critical in determining and assigning a meaningful impact and vulnerability rating to an asset.

Each council asset type will be influenced by, and have different levels of sensitivity to, particular hazards. A key aspect of this vulnerability assessment was to determine the likely exposure over time to hazards (such as heat waves, storm surge events and sea level rise).

The first pass assessment, or high-level assessment applied in this study used spatial analysis to assign a high-level vulnerability assessment rating to council assets for different climate variables.

2.4. Case Studies on how we plan for climate change and its impacts

More detailed vulnerability assessments were undertaken in the form of case studies, which have been termed a second pass assessment process in this project.

These case studies use a scenario (or set of) to describe how a particular extreme weather event that is exacerbated by climate change, impacts a particular location and how the impacts can be reduced through adaptation measures. The adaptation responses presented range from broad strategic evaluations through to local planning related responses. The results were aimed at assisting higher level decision making by council officers and managers rather than finer level planning decisions.

Due to the sensitive nature of some of the information in the case studies, the information has not been included in this report. However, the process has been documented and will be included in the AVA process toolkit to be found on the SECCCA web-site.

The three case studies selected from the 19 candidate case studies nominated by councils for consideration, and for which separate and more detailed analysis was undertaken, were:

- Port Phillip - Inundation at Elwood Foreshore
- Mornington Peninsula - Inundation at Rosebud
- Cardinia - Bushfire at Gembrook and Cockatoo

Details concerning these case studies, including the adaptation options considered and financial analysis undertaken are contained in separate case study reports.

2.5. Extreme Weather Events and Climate Change Projection Data

While extreme weather events are not readily modelled in the latest climate science and down-scaled modelling available through the CSIRO, the latest modelling outcomes were used to help contextualise key trends in the climate data that directly influence likely extreme weather events for the region. For example, the locations where daily rainfall is anticipated to exceed a particular threshold at a future date under a particular scenario was identified.

2.6. Alignment with CMSI

This project, including the development of the second pass case studies, is aligned with the Climate Measurement Standards Initiative (CMSI) in terms of principles, concepts and definitions and methodologies applied.
The overarching principles of the CMSI are:

1. Use credible scientific sources, assessments and research published in peer-reviewed scientific literature or from reputable scientific authorities.
2. Use multiple lines of evidence to assess risk and, where possible, use existing assessments of multiple lines of evidence.
3. Where possible and appropriate, survey multiple model ensembles.
4. Appropriately communicate uncertainty.
5. Use model outputs appropriate for the question addressed.

The principles have been further developed by the CMSI to advise:

- support for international standard Representative Concentration Pathways (RCPs) as plausible trajectories.
- using a range of plausible regional climate change. A broad range of possibilities can be considered, including consideration of a ‘best case’ or ‘worst case’ change if that is more useful.

- before using a climate projections dataset for assessing impacts, the projections should be examined to ensure they are fit-for-purpose.
- developing hypothetical scenarios to 'stress test' systems that invoke compound events is recommended where feasible.

A detailed explanation of these principles, concepts and definitions is provided in *Scenario analysis of climate-related physical risk for buildings and infrastructure: climate science guidance* (CMSI, Earth Sciences and Climate Change Hub, 2020).

2.7. How do we plan for climate change and its impacts?

Having identified the anticipated impact of change, the key issue for councils is what to do about it. These issues will be explored in the more detailed second pass vulnerability assessments undertaken in the form of case studies which will include a review of anticipated costs in relation to specific climate related impacts.

3. Our Vulnerability Assessment Approach

3.1. Use of recent climate change modelling data

The asset vulnerability assessment approach applied in this project will use the most recent climate projections for Victoria the Victorian Climate Projections 2019. The Victorian Government worked with CSIRO to provide dynamically downscaled 5km x 5km state wide projections for six Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report (AR5) global climate models. This application ready data has been applied in this project.

These modelled climate variables and associated impacts, as outlined in the previous chapter, will be processed into a vulnerability rating.

3.2. Vulnerability Method Overview

The concepts and definitions adopted in this project will draw on elements of the overall vulnerability assessment method as outlined and adopted in: Guidelines for Developing a Climate Change Adaptation Plan and Undertaking an Integrated Climate Change Vulnerability Assessment; November 2012; Local Government Association of South Australia.

This method describes how likely exposure to climate scenarios, coupled with the sensitivity and adaptive capacity of the asset to these climate scenarios, are used to assess the likely vulnerability of assets to these changes. This process was developed by the Allen Consulting and is based on that developed by the IPCC. (Brunckhorst, 2011)

The conceptual framework and definitions on which this process is based are described in Appendix 3.

This approach generates an impact rating based on the assessed inherent sensitivity of an asset to different climate change parameter exposure scenarios. The adaptive capacity of an asset in relation to impacts is also assessed and used to assign asset vulnerability, where adaptive capacity primarily relates to attributes that can be altered, such as the condition or context of an asset.

Spatial datasets depicting council assets will be utilised in this process.

3.3. Climate Change Variables and Inundation Impacts

Areas likely to be impacted by some climate change variables, such as those be subject to increased overland flooding due to increased rainfall events, are differentiated across the region and municipalities at a finer scale than anticipated climate change variables such as heat waves and rainfall variation. While anticipated climate related changes, and the impacts on individual assets will also vary across the region and municipalities based on the asset location, climate variable data is still at a very coarse 5km by 5km resolution, and hence will be applied to an entire asset.

Given the variation in resolution between inundation modelling and modelled climate variables such as temperature and rainfall, it is proposed that the following two approaches be undertaken to assess the likely impact of climate change based on the type of climate change information.

These are:

1. Vulnerability assessment
2. Inundation Profile

Vulnerability assessment

The first pass vulnerability assessment will be conducted for each asset grouping (that comprise buildings, roads, drainage and open space) and applied at the individual asset level. This impact assessment will assist in understanding the climate parameters that are driving the assessed vulnerability rating in that it reflects how the anticipated 'broader' climate change under each climate change scenario - using latest climate projections for Victoria (Clarke et al 2019) prepared by CSIRO - likely to broadly impact on each asset group.

During the data collation stage, asset data provided by each member council will be assessed for completeness and suitability for a vulnerability assessment.

While all assets will be assigned a vulnerability rating, the final rating assigned will be dependent on available council data.

For some assets, a generalised rating, or in some situations, no first pass vulnerability assessment rating, may be assigned. Assets for which this applies includes those with:

- 'ghost' entries such as assets held by other non-council aligned organisations, but still being recorded spatially by council in asset management systems,
- incomplete data records from information held by third parties,
- incorrectly entered or incomplete data, or
- data that is not captured 100% for a given attribute or asset, such as condition for underground pipes

Inundation profile

An inundation profile will be applied to all agreed Council assets and will involve using detailed spatial data for inundation (from anticipated sea level rise and flooding scenarios) and potentially coastal erosion (from Local Coastal Hazard Assessments and other sources).

In applying these two assessment approaches the following two categories of asset assessmentresults will be prepared to assist users:

1. Vulnerability assessment based on asset attributes.
2. Inundation assessment profile based on inundation extent (for coastal, riverine and urban inundation scenarios).

3.4. Asset Vulnerability Assessment – First Pass Approach

A first pass asset vulnerability assessment will involve using individual asset characteristics to assign a likely estimate of an asset's sensitivity to particular climate change variables, and features of the asset impacting its adaptive capacity to such change. Suitable asset attribute information is required to support such an assessment.

A review of how individual asset attributes will be used to support such an assessment will be undertaken and agreed with Council staff.

The final approach adopted for each asset type and climate change variable will be agreed with the Project Technical Reference Group prior to implementation.

Figure 1 presents how a Vulnerability Assessment Framework will be applied in the SECCCA project. As indicated, this framework has been developed by the International Panel on Climate Change (IPCC 2001, IPCC 2007) and previously applied in multiple climate change vulnerability assessments (Spatial Vision 2013, 2021) (Spatial Vision 2020).

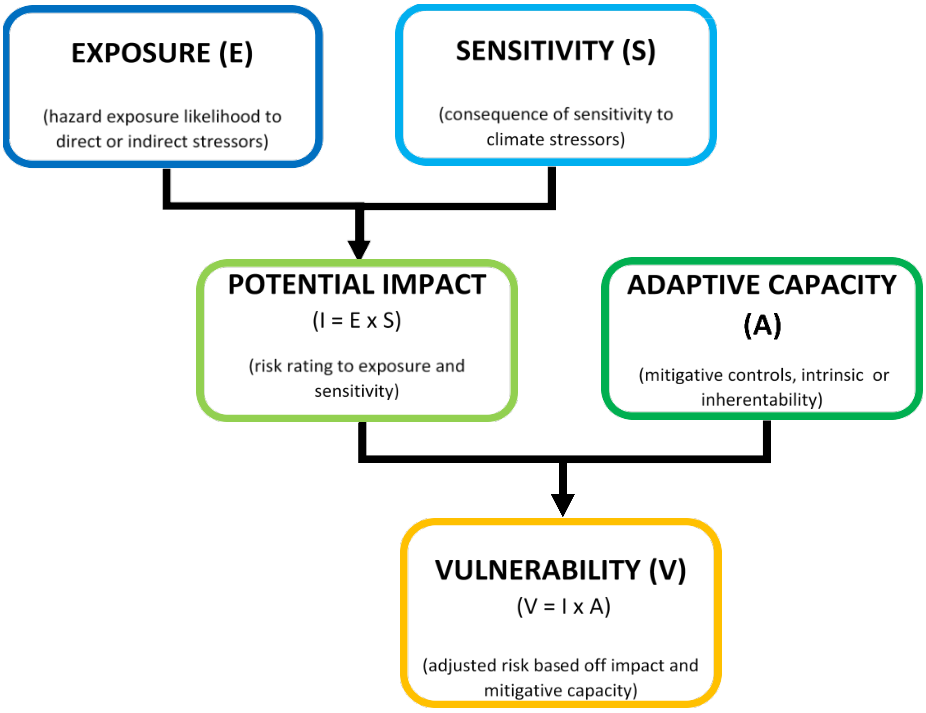

Figure 1. Proposed conceptual framework for assessing vulnerability to climate change.

Key definitions relating to this framework are detailed briefly below, with a longer definition provided in the glossary in Appendix 2.

Vulnerability: The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability (in relation to climate variables) and extremes.

Exposure: relates to the changes in climate variables, influences or stimuli that impact on a system (such as heat waves, or sea level rise).

Sensitivity: reflects the responsiveness of a system to climatic variables, and the degree to which changes in climate might affect that system in its current form. This responsiveness relates to 'inherent' characteristics of the asset to deal with a particular climate stressor.

Adaptive Capacity: is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Impact: refers to the effect on the natural or built environment to particular climate variables or hazards, including extreme events such as heat waves, storms and other climate events.

For the purposes of this project, adaptive capacity will be assigned in terms of the ability of the asset to adjust to climate variables based on its current state rather than a projected future state.

As an example, assuming it was applied to council managed buildings:

- Exposure would include hazards such as heatwaves, or more days over 35°C, or greater dryness influencing foundations. These are identified as potential key climate variables,
- Sensitivity attributes would relate to roof, foundation or external wall material, asset function and age,
- Adaptive Capacity factors that may be considered in reducing vulnerability are identified as building condition, where a well maintained building will be less vulnerable to the same climate change than a poorly maintained building.

In relation to climate-related changes (or exposure to them), ratings and scores for exposure are provided through the initial climate analysis. Translation tables to convert above-normal climate-related changes to ratings, or probabilities will be generated. From these tables, scores can be applied to a stressor for each emission scenario over the different time points. For example, a small change in Mean Maximum Daily Temperature would be assigned a low value (of say '1') and a large change a high value (a value of 5).

Similar with Sensitivity and Adaptive Capacity factors, scores will be generated and applied back to a range of attributes inherent within the asset. These will then be combined with exposure scores to calculate an overall Vulnerability score.

The full application and assignment of these values are expanded upon in Section 5.

3.5. Inundation Profile Approach – First Pass Approach

Sea level rise and associated storm surge, overland flow or flood events and coastal erosion, are climate-related variables that can be applied as a differentiated change across the municipality. For these two variables an inundation profile for all individual council assets will be undertaken.

This profile comprises the following three key elements for each climate change variable assessed:

- absolute extent (area or length) of the asset impacted.
- percentage of the total asset extent that this impacted extent represented.

- cost to impacted extent based on replacement valuation and maintenance cost data for assets (provided by Council, where available).

This process will generate a profile for each asset that provides both absoluteasset quantity values and percentage breakdowns for each category.

The profile will provide a summary of the climate change related impact ratings for an asset. An example of the type of asset profile report that will be generated is presented in Table 1.

Table 1. Example output report for polygon feature type asset

	Feature type	Unit	Quantity (sqm)	Heatwave (3 days over 35C) (sqm)	Sea Level Rise – 82cm (sqm)	Sea Level Rise (82cm) and 1% AEP Storm Surge Event (sqm)	Flooding 1% AEP (sqm)
Asset A quantity %	polygon	ha	60.16	60.16 100%	45.58 80.8%	51.9 86.3%	53.15 88.4%
Asset B quantity %	polygon	ha	5.05	5.05 100%	3.37 66.7%	5.05 100%	5.05 100%

4. Climate Data and Scenarios

4.1. Climate Change Data

Several climate change related variables and impacts are to be assessed to identify 'high risk' or priority assets within the SECCCA Study Region. These climatic related variables include:

- Temperature (minimums and maximums)
- Extreme temperature and heat waves (defined as 3 or more consecutive days above 35C)
- Rainfall (monthly and seasonal)
- Extreme rainfall and rainfall deficiencies (Dryness Index)
- Overland flooding
- Sea level rise (inundation and erosion)

The following sections will explore each of these variables in more detail, primarily around the use of data and available sources that can be leveraged in the process of a climate impact and vulnerability assessment.

4.2. Inundation Climate Change Events

The overall first pass Asset Vulnerability Assessment will include consideration of the following three inundation events:

- Sea Level Rise of 82cm
- Sea Level Rise of 82cm with 1% Annual Exceedance Probability (AEP) Storm Surge Event
- 1 in 100 year Flood Event based on historical data

An inundation profile will be prepared for each individual council asset (in the agreed asset classes) for these three inundation events.

4.3. Projected Climate Change and Climate Change Related Events

The first pass asset vulnerability assessment will include consideration of the following projected climate change variables that will be derived from the most recent climate modelling prepared by CSIRO and made available as part of the Victorian Climate Projections 2019 Project:

- Number of annual hot days (defined as days with a max temp greater than 35C)
- Degree increase of annual extremely hot days (defined as change that occurs to top 1% of events)
- Number of annual heat waves (defined as three or more consecutive days greater

than 35C)

- Percentage change of annual extremely wet days (defined as change to events that occurtop 1%).
- Number of months in a given year in which a dryness index measure falls below a threshold value (based on a Standard Precipitation Index approach).
- Percentage change in annual rainfall (from baseline)

The baseline climate data will be the same as that used in the VCP2019 project which is the period 1981 to 2010.

The VCP2019 projections comprise downscaled, application-ready data derived from the most recent climate modelling prepared by CSIRO as an outcome of the IPCC 5th Assessment Report (AR5).

In relation to the application of these climate variables it is proposed that the two most critical projected climate variables likely to impact the vulnerability of an individual asset by type be considered.

Preliminary thoughts on which projected climate change variables to apply to asset types on this basis are presented in Table 2.

Table 2. Initial thoughts of the two or more most critical projected climate variables likely to impact the vulnerability of individual assets by type

Projected climate change variables	Buildings	Drains	Road	Open Space
Number of annual hot days				●
Degree increase of annual extremely hot days	●		●	●
Number of annual heat waves	●			●
Percentage change of annual extremely wet days		●	●	
Number of months that dryness index falls below agreed threshold value	●	●	●	●
Percentage change in annual rainfall				●

Application of the latest climate change data from CSIRO will involve evaluating relevant annual and monthly climate variable data for agreed carbon emissions scenarios. This information has been prepared for presentation in a spatial data viewer with a supporting graph-based view of these key climate variables. Evaluation of likely change for the periods of 2030, 2050, 2070 and 2090 and historical decadal information will be used to inform trends in key variables such as rainfall and daily maximum temperatures.

Views of future heat wave events for the SECCCA region are presented in Figure 2. This map view shows the significant variation in the frequency of heat wave events across the region anticipated in the year 2070, where orange represents the higher level of heat wave frequency. The graph view shows the change from a baseline period (on the left in grey) to 2050 (on the right in red).

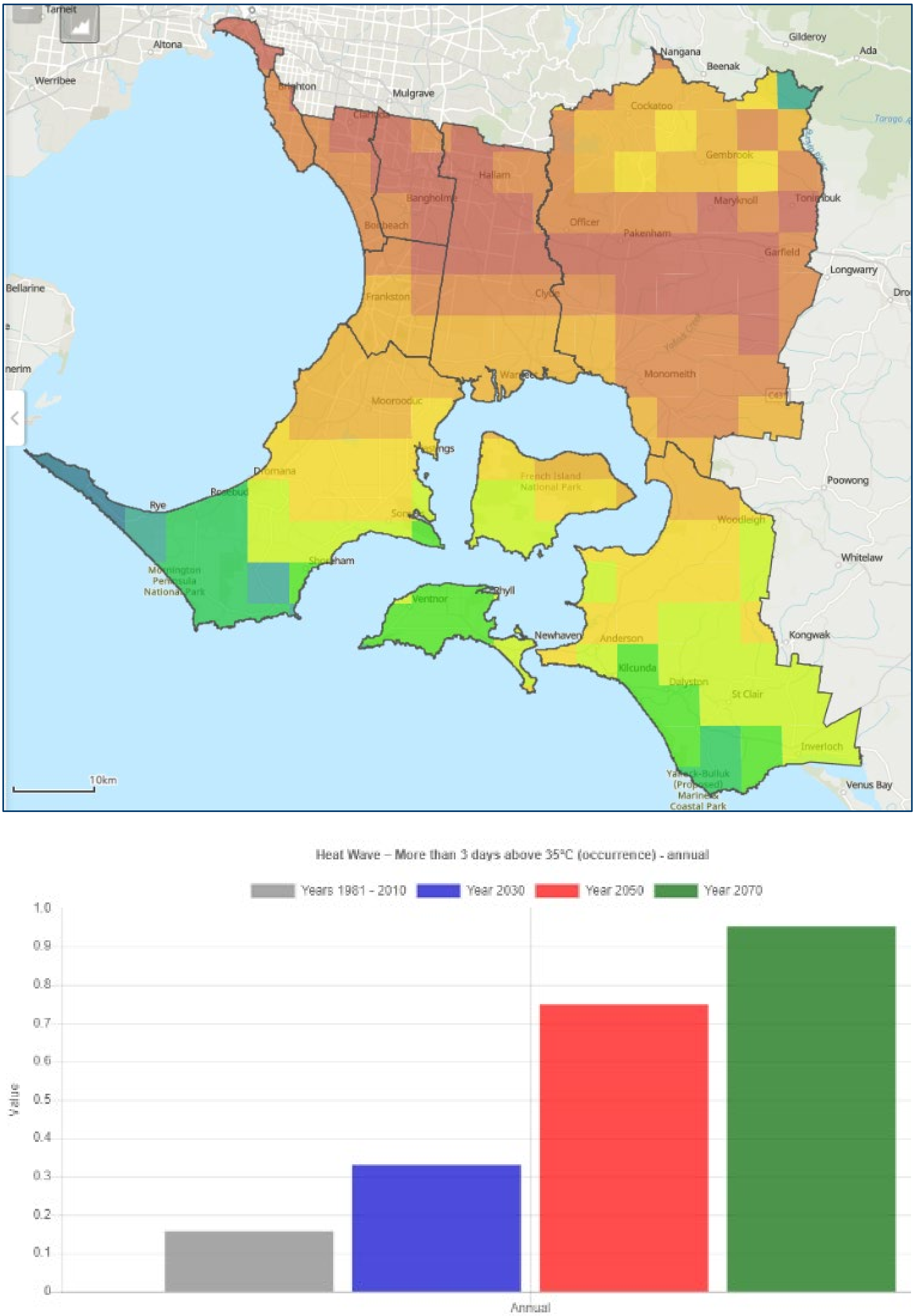

Figure 2. Views of future heat wave events (under ACCESS 1.0 GCM and RCP8.5) for the SECCCA region (map view is for 2070).

4.4. Climate Models and Climate Scenarios

In line with the Climate Measurement Standards Initiative (CMSI) a range of General Circulation Models (GCM) will be selected, representing:

1. Maximum consensus future climate (based on all six available VCP19 models (Clark et al 2019))
2. Hotter and drier future climate
3. Warmer and wetter future climate

This approach is also in line with climate change modelling advice provided directly by the Project Technical Reference Group that have advised that futures represented by each GCM are equally possible and ideally 2 or 3 different GCMs should be considered in any vulnerability evaluation. The proposed approach to incorporate a range of possible futures is presented in Section 6.

The three models selected to represent the range of likely futures for both temperature and rainfall projections include the NorESM1-M, HadGEM2-CC and ACCESS 1.0 GCMs,where these models have been developed by:

1. ACCESS 1.0 - CSIRO and BoM – representing a maximum consensus future
2. HadGEM2-CC - Met Office Hadley Centre – representing a hotter and drier future
3. NorESM1-M - Norwegian Climate Centre – representing a warmer and wetter future

4.5. Carbon Emission Futures

In terms of climate projections based on carbon emission future scenarios, while SECCCA have expressed interest in the Representative Concentration Pathway (RCP) emissions scenarios of 4.5 and 8.5 (RCP4.5 and RCP8.5), the CMSI proposes use of a lower emissions scenario represented by RCP2.6.

The VCP2019 projections are only available for an RCP4.5 and RCP8.5 carbon emission future.

To assist compliance with the CMSI principles, CSIRO together with DELWP have provided guidance on how RCP4.5 climate projection data can be downscaled and converted to model a RCP2.6 future. Hence, this project will apply, where appropriate, a RCP2.6 future that encompasses an ideal scenario of curtailing changes to warming less than 1.5°C (RCP 2.6).

The relationship between an RCP4.5 and RCP2.6 future is presented in Table 3 which has been formulated by Dr Michael Grose (Climate Projections Scientist, CSIRO). Michael has been assisting with the development of CMSI and has provided this advice to assist with the translation of an RCP4.5 future to an RCP2.6 scenario. This translation can be applied to each of the three climate models at each time frame for each respective climate variable.

Table 3. RCP4.5 to RCP2.6 conversion factor table

Period centred on:	RCP2.6	RCP4.5
2030	+0.7 °C annual temp	+0.7 °C
	-3 % annual rainfall	-4%
2050	+0.8 °C	1.1 °C
	-4%	-4%
2090	+0.8 °C	+1.5 °C
	-5%	-5%

The first pass vulnerability assessment will present the findings for an RCP4.5 future, and an RCP8.5 future.

RCP 2.6 futures will be processed and presented for several selected assets to examine these outputs, but will not be run for the full asset data collection. How RCP 2.6 projections will be used and presented for the project as a whole will be discussed and decided with the SECCCA project team during the course of the project.

4.6. Time Frames

The VCP2019 projections are available for the years of 2030, 2050, 2070 and 2090.

This projection data is based on a baseline climate represented by the period from 1981 to 2010. It is proposed that while the project will compile and review the projection data for all four future time periods, there will be a focus on presenting results and outputs for the period up until 2050. Inclusion of three models for two RCPs and four time points, will result in a significantly large volume of data and outputs. Reporting and presentation is largely suggested to focus on one time-point to present the context of the results, but other points can be bought in to further expand discussion.

It is noted that for the period to 2030 changes in the projections between any GCM at both RCP 4.5 and 8.5 may be minimal, but periods after will have larger differences (see below Figure 3). (IPCC 2007)

We also propose investigating the use of existing climate observation data to see how some climate variables are already changing.

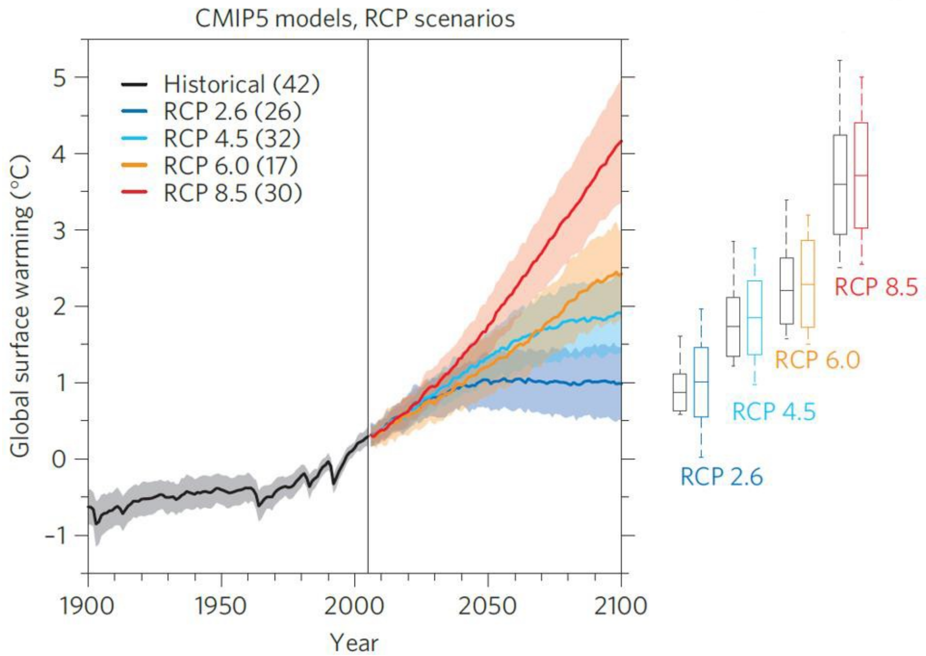

Figure 3. Relationship between four RCP scenarios, where RCPs provide standardised greenhouse gas concentration inputs for running climate models.

4.7. Other Climate Variables

Fire Risk Index

A fire risk index, as a single variable measure, will not be included in the vulnerability analysis.

Fire risk and bushfire variables were thought to be something that could be included as a single variable in the assessment. Through subsequent discussions with the SECCCA Technical Reference Group, in particular Ramona Dalla Pozza (DELWP) and Dr Roger Bodman (CSIRO), who is undertaking fire variable analysis for DELWP as part of the VCP19 program, it is understood that a single index will not provide an accurate indication of fire change and risk into the future.

Therefore, a range of key variables will be adopted and assessed. These include dryness, rainfall trends and temperature increases, which can be used in combination to indicate areas likely to experience an increase in fire danger.

Secondary data layers, such as bushfire management overlays, and fuel load information may also be considered. Tom Davies (Insurance Council of Australia) has advised that the ICA primarily makes use of Bushfire Management Overlays in their assessments.

Figure 4 presents a conceptual framework that identifies four factors that influence fire regimes or risks in a landscape. The figure indicates that while fuel load is influenced by climate or growing conditions, climate also impacts the other elements of the framework including fuel dryness (and hence flammability), fire weather, and likelihood of an ignition source, particularly lightning.

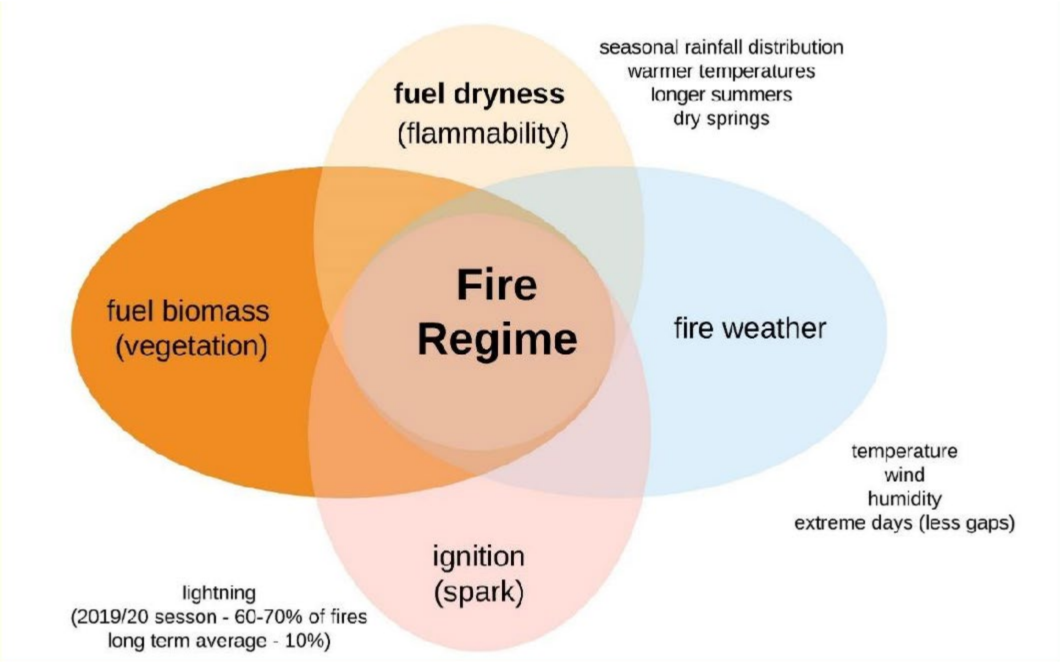

Figure 4. Relationship between climatic variables and landscape factors associated with increase fire risk

As indicated in the figure, climate variables, such as seasonal rainfall distribution or deficiencies, temperature changes, dryness indexes and extreme days in relation to rain or temperature, can be used to provide context behind fuel dryness and fire weather.

This framework supports the adoption of key variables such as changes on seasonal rainfall, monthly temperature and dryness to assess likely fire regime impacts.

Wind Speed

Current observed and future climate change data projections for wind factors is another variable that was explored by the project team for inclusion in the project. The VCP19 database includes wind speed as part of their suite of variables. However, it is at a coarser time scale of monthly periods and not available as daily data (as provided for other climatic variables).

Further, the available data only presents average projected wind speed over a given month, and not details on wind direction and wind gust speeds. Further to this, the available data does not show any significant variation in monthly wind speed for any of the climate scenarios.

As such the data is more generalised than what is required for a vulnerability assessment and will not be used.

5. Key asset attributes to assess vulnerability

The vulnerability of an asset is highly dependent on, amongst other things, the asset's age, materiality, level of service and use. For the purpose of this project, these factors have been termed attributes and have been used to identify the likely sensitivity or adaptive capacity of an asset to climate change.

Initial thoughts of asset attributes to be used in the vulnerability assessment based on a preliminary review of the SECCCA council attribute data obtained for building, drainage, road and open space assets is presented in Table 4. The table identifies the attributes that are suggested in relation to the assignment of a sensitivity rating, and attributes that are potentially an indicator of adaptive capacity.

Table 4. Initial thoughts of attributes to be used in vulnerability assessment based on a preliminary review of the SECCCA council asset attribute data

	Sensitivity				Adaptive Capacity			
Asset Attribute	Buildings	Drains	Road	Open Space	Buildings	Drains	Road	Open Space
Material	●	●	●	●				
Hierarchy	●		●	●	●			●
Level of service	●			●	●			●
Type	●	●		●	●			●
Condition					●		●	
Design life	●	●				●		
Useful age	●	●				●		
Install date	●	●				●		
Age	●	●				●		
Vehicles per day							●	
Depth		●						
Diameter		●						
Context								
Area				●				
Perimeter				●				
Population		●		●				
Proximity to water		●	●	●				
Proximity to roads				●				

Some of the asset attributes, depending on each council's usage, are interchangeable. For example, hierarchy, level of service and type can be the same attribute in one area, or mean completely different things in another council. How these attributes will be used, between adaptive capacity or sensitivity has been determined via a series of initial data collation meetings where the Spatial Vision team talked to each council group to help understand the context of their data and ensure that the data will be used in an appropriate manner.

6. Approach in assigning final ratings

6.1. Assignment of Asset Vulnerability Ratings

The first pass asset vulnerability assessment will involve applying a vulnerability assessment for two to three agreed projected climate change variables for each asset, as presented in Table 2 and reporting on the outcome of each.

Hence, for each asset class (buildings, roads, drainage and open space), there can be up to three individual vulnerability assessments. These results may be combined on the basis of, either the worse rating, a weighted approach, or another approach to combining the results.

This first pass asset vulnerability assessment process will be applied for the agreed projected climate change variables for each climate scenarios, for each future time point. This can result in each asset having three vulnerability scores, for three projected climate change scenarios, under two RCPs under four time points.

In relation to the four time points (2030, 2050, 2070 and 2090) it is proposed that a key reference year of 2050 be used to review and present the first pass asset vulnerability assessment findings.

Relative Climate Changes Application

For each of the three climate projection scenarios, or possible futures (RCPs), relative change from a baseline will be determined rather than absolute values.

These changes will be classified into categories of change ranging from '1 Very Low' to '5 Very High', which can then be used as the basis for identifying the likely exposure of assets to various levels of climate change. An example of this classification is shown in Table 5 as applied to temperature variables.

Table 5. Example of climate relative change classifications for temperature variables.

Change		Degree change from baseline - temperature	Day change from baseline – very hot days (35C)	Day change from baseline – heat wave	Description
Very High	5	> 2.0°	> 4 days	> 0.8 days	Extreme Increase (i.e., Much Hotter)
High	4	1.5° – 2.0°	3 – 4 days	0.6 – 0.8 days	Major Increase (i.e., Hotter)
Moderate	3	1.0° – 1.5°	2 – 3 days	0.4 – 0.6 days	Moderate Increase (i.e., Warmer)
Low	2	0.5° – 1.0°	1 – 2 days	0.2 – 0.4 days	Small increase (i.e., Slightly Warmer)
Very Low	1	0.0° – 0.5°	0 – 1 days	0 – 0.2 days	Little to no change

This output is then fed into the exposure arm of the vulnerability framework.

Sensitivity and Adaptive Changes Application

Sensitivity

A key consideration for a given asset (or asset type) is what asset attributes would make any given asset more or less sensitive to a particular climate variable (such as heat waves or more hot days).

The rating system proposed is to assign a score between 1 and 5. A score of '1' indicates assets with

a particular characteristic that makes it less sensitive (more resilient) the variable and '5' indicates assets with a particular characteristic that makes it more sensitive (or less resilient).

This sensitivity relates to particular characteristics or attributes of the asset that are essentially an intrinsic element of the asset that cannot be readily changed.

For example, a tree may be a particular species or age that makes it more or less sensitive to heat.

Adaptive Capacity

Similar, Adaptive Capacity is a characteristic of a given asset (or asset type) that makes it more or less resilient to a particular climate variable (such as heat waves or more hot days).

The rating system proposed is to assign a score of between 1 to 5. A score of '1' indicates assets with a particular characteristic that makes it have a higher adaptive capacity (more resilient) to the variable and '5' indicates assets with a particular characteristic that makes it have a low adaptive capacity (less resilient).

This adaptive capacity relates to particular characteristics or attributes of the asset that can be modified through adaptive features or mitigative actions.

For example, a tree may be a well maintained, or have irrigation facilities put in that will make it more resilient to a given variable, such as heat.

Table 6 identifies the sensitivity and adaptive capacity ratings and definitions assigned to asset attributes or characteristics.

Table 6. Sensitivity and Adaptive Capacity ratings and definitions

Score	Sensitivity	Adaptive Capacity
1	Very low sensitivity to exposure	Very high adaptive capacity
2	Low	High
3	Moderate	Moderate
4	High	Low
5	Very high sensitivity to exposure	Very low adaptive capacity

Application to Attributes

For each Council, for each assigned sensitivity or adaptive capacity attribute, values within data layers will be classified into these 1 to 5 classification systems based on values within attributes.

An example is provided in Table 7 for some sensitivity attributes for buildings and roads. Ratings, attributes and values will differ between council areas, hence scoring can change.

Table 7. Sensitivity classification examples for Roads and Buildings.

Attribute	Value	Score	Comment
Level of Service	Aquatic and Leisure	2	LoS can define how often an asset is maintained or how robust/well built an asset is. Higher LoS, greater maintenance or greater design integrity as it is built for a higher level of purposeor life.
	Community	3	
	Corporate	2	
	Libraries and Arts	3	
	Public Toilets	4	
	Special Purpose	3	
	Sports and Recreation	2	
	Structures	4	
Level of Service – Road Hierarchy	Arterial	5	
	Citylink	5	
	Council Major	4	
	Council Minor	3	
	Freeway	5	
	Lease/Reserve	1	
	Parks Victoria	1	
	Port Roads	2	
	Private	1	
	Proposed Public	3	
Design Life	0 or None	3	Higher design life can indicate greater resilience to climate variables
	15	5	
	20	5	
	24	5	
	25	4	
	30	4	
	40	3	
	50	2	
	100	1	

Application of scores to any attribute group is considered in isolation to other attributes and only in relation to the exposures in questions. Links between attributes will not be considered.

Once all layers are processed, there is an overlaying process which assumes all input layers are equal. To this end, there should be consideration of the number of inputs into the overlaying processing.

If there are too many layers, there can be an over-saturation of inputs. What may happen is that all scores will even out into a neutral score. As such, it is recommended to only have somewhere up to 3 attributes per type (sensitivity or adaptive capacity) to capture the critical attributes to the particular asset grouping.

Asset Attribute and Climate Assignment Quality Assurance

The process for assigning a sensitivity and adaptive capacity rating to assets will involve a review of available asset attributes and an evaluation of their suitability for use in the assessment.

As the project team will apply the rating values for adaptive capacity and sensitivity in relation to climatic variables based on asset data attributes.

For climatic variable ratings, the first step in the process will be to assess the range of values for each climate variable and the change relative to a baseline (ie. changes in the average rainfall). This will be used together with the insights obtained from previous studies, to assign a score range appropriate for each climate variable and asset type across the SECCCA project area.

How these relative changes in a climate variable relate to assets and the rating assigned for sensitivity and adaptive capacity will also draw on the insights obtained from previous studies. The project team have gained a good understanding of what principles to apply and the scores to assign in this process. This has been tested with relevant field experts, asset managers in previous studies and literature reviews and research undertaken in prior projects (Fussel and Klein 2006), (Spatial Vision 2013, 2021), (Spatial Vision 2020).

This process draws significantly on work undertaken in collaboration with Professor Roger Jones from Victoria University (Professorial Research Fellow, Institute for Sustainable Industries & Liveable Cities). His knowledge on urban ecology and climate risk assessment has been invaluable in framing an understanding how urban environs and assets respond to projected changes in the climate.

The first pass vulnerability assessment process will involve a review and subsequent refinement stage following an initial application of the assessment process. This review and validation stage is critical for quality assurance purposes.

Asset sensitivity and adaptive capacity ratings assigned on the basis of asset attributes will be discussed and reviewed with relevant asset managers in SECCCA member councils prior to their application, to ensure local knowledge is captured in the process.

6.2. LGA Asset Data Considerations

Asset spatial representation

The first pass vulnerability assessment process requires a spatial delineation of all assets in either point, line, or polygon representation. Point based data can also be provided as a spatial spreadsheet, provided this information includes fields that identify point coordinates to map it back to the spatial domain.

The sensitivity and adaptive capacity attributes may be provided as attributes in the spatial datasets, or provided in tables that can be linked to assets based on asset ID values.

Asset data attributes

The attribute details provided for particular assets will determine the level of detail of the sensitivity and adaptive capacity ratings. Assets with little attribute information will be placed in a general category and will be assessed based on more general rules with respect to their sensitivity to climate variables or their adaptive capacity factors.

More detailed sensitivity or adaptive capacity ratings will be assigned where more detailed attribute information supports this based on known relationships.

This assessment approach does not replace the need for on-site evaluations to support operational response decisions.

A key outcome of the project is to provide a framework and an approach that can be reviewed and refined with new and more detailed knowledge about the likely relationships between asset attributes and climate change variables.

Data cleaning

Processing of data (based on previous studies) for use in the assessment process will involve:

- Standardisation in format, projection, and structure as required.
- Missing attributes or attribute values assigned as required.
- Removing duplicate datasets and features.
- Assigning a master version where there are multiple versions of the one dataset.
- Consolidating data based on agreed rules where multiple datasets for the one asset cover the one LGA.
- Undertaking an attribute type alignment process (where different types of classification are used)
- Addressing overlapping features etc, where data may cross LGA boundaries.

This process involves ensuring the data is suitable for use in the first stage of the vulnerability assessment which will be undertaken on ArcGIS.

Spatial data will be standardised into one common spatial format and file type for use throughout the project.

Additional details on LGA asset data collation and processing are provided in a separate document, which will be finalised at the conclusion of the first pass asset vulnerability assessment stage of the project.

The Impact Finding Report that will also be prepared at the completion of the first pass asset vulnerability assessment stage will describe the final process applied and inputs used to generate the final vulnerability ratings for each asset type.

Data provision post project completion

The final stage of the project will involve providing all datasets back to SECCCA LGAs in this same format with the original LGA assigned asset attributes, in addition to asset vulnerability attributes added through the vulnerability assessment process.

This data will be provided together with a supporting QGIS (GIS software) project that will allow the data to be visualised, evaluated and queried. This environment will also support mentoring in the analysis process undertaken to assess and assign asset impact and vulnerability.

6.3. Climate Impact and Vulnerability Application

The vulnerability assessment process described will result in a significant number of vulnerability ratings (or range in vulnerability rating scores) for individual assets.

A key component of the process is the asset impact assessment rating for each climate variable assessed based on an assigned sensitivity of an asset to the anticipated change.

Adaptive capacity assigned at the asset level is then used in combination with the assessed impact to determine a final vulnerability assessment rating.

The results of this process for three climate models will be used to assign climate model based vulnerability ratings for an asset.

This process will be repeated for each combination of the four future time points under consideration (2030, 2050, 2070, and 2090), and for each RCP scenario (RCP4.5 and RCP 8.5).

Hence, each asset will have a vulnerability assigned based on multiple climate change variables, for three global climate models, four time points, and two carbon emission futures.

6.4. Proposed process in applying asset vulnerability assessment

In terms of a process to apply the AVA Part 1 outcomes, it is suggested that the maximum consensus climate model outcomes (which for the SECCCA region is ACCESS 1.0) can be used as a starting point, and that the outcomes under a hotter and dryer, and warmer and wetter future (based on the other climate models – HadGEM2-CC and NorESM1-M respectively) be explored in relation to this maximum consensus climate model future.

It is proposed that the vulnerability results for the year 2050 and an RCP8.5 emissions future should be used as the starting point to review vulnerability assessment outcomes.

Mentoring sessions scheduled for the AVA project will focus on this process in relation to the application of assessment results for selected individual assets, and summary vulnerability results on a locality basis.

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Appendices

Appendix 1: Acronyms

AEP	Annual Exceedance Probability
AR5	(IPCC) 5th Assessment Report
BOM	Bureau of Meteorology
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CMIP5	Coupled Model Inter-comparison Project, Phase 5
CSMI	Climate Measurement Standards Initiative
DELWP	Department of Environment, Land Water and Planning
GIS	Geographic Information System
GCM	Global Climate Model
ICA	Insurance Council of Australia
IPCC	Intergovernmental Panel on Climate Change
LGA	Local Government Area
RCP	Relative concentration pathways for carbon emissions
SECCCA	South East Council Climate Change Alliance
SILO	Scientific Information for Land Owner
SLR	Sea Level Rise
SPI	Standardised Precipitation Index
STM	Storm Surge
SV	Spatial Vision
VCP19	Victorian Climate Projections 2019 (See: Clarke et al 2019)

Appendix 2: Glossary

The following definitions below were used through this project and may have been alreadyoutlined in the preceding text. These draw significantly on the IPCC (2007) definitions.

Acute: Climate change events that refer to climate exposures or variables that have a short time frame and sharp response. Can relate more so to extremes in climate or flooding/storm events, the extreme 1% Annual Exceedance Probability (AEP) events or 1 in 100-year events.

Adaptation: Adjustment in natural or human systems in response to actual or expected climatic variables or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation

Anticipatory adaptation – Adaptation that takes place before impacts of climate change are observed. Also referred to as proactive adaptation.
Autonomous adaptation – Adaptation that does not constitute a conscious response to climatic variables but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. Also referred to as spontaneous adaptation.
Planned adaptation – Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state.

Adaptive Capacity: is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with theconsequences. The adaptive capacity of a system or society describes its ability to modify its characteristics or behaviour so as to cope better with changes in external conditions. The more adaptive a system, the less vulnerable it is. It is also defined as the property of a system to adjust its characteristics or behaviour in order to expand its coping range under existing climate variability or future climate conditions. For the purposes of this project, adaptive capacity has been considered in terms of the ability of the asset to adjust to climate variables based on its current state

Attributes: Refers to parameters or features of an asset that are described in the form of database fields. These range for the materials from which the asset is built, to the maintenance schedule for an asset.

Chronic: Climate change events that refer to climate exposures or variables that are a long-term variable with a slow response. Mainly relates to climate change over time, for example, temperature increases over time.

Exposure: relates to the influences or stimuli that impact on a system. Exposure is a measure of the predicted changes in the climate for the future scenario assessed. It includes both direct variables (such as increased temperature), and indirect variables or related events.

Hazard: refers to a process, natural or otherwise, that has the potential to impact on a given area to a degree that assets associated with that location may be at risk. In the context of coastal areas, these hazards are primarily naturally driven and can include processes such as storms and sea level rise. However, anthropogenic influences on these processes are indirectly increasing the impact of the hazards.

Impact: refers to the effect on the natural or built environment to particular hazards, including extremeevents such as storms and other climate events. It relates to the exposure of an asset to a particular hazard and the sensitivity of that asset to that exposure.

Mitigation: An anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks.

Risk: is the potential of losing or gaining something of value based on particular actions or inactions.A risk assessment, or analysis, is the process in which these potential risks are evaluated, and the projected consequences are defined based on this action or inaction.

Resilience: The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change.

Sensitivity: reflects the responsiveness of a system to climatic variables, and the degree to which changes in climate might affect that system in its current form. Sensitive systems arehighly responsive to climate and can be significantly affected by small climate changes. This term is often used interchangeably with the term susceptibility.

Spatial view: An online or hardcopy map view of spatial data

Vulnerability: The degree to which a system is susceptible to, or unable to cope with, adverse effectsof climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity

Appendix 3: Proposed Vulnerability Assessment Framework

The broader concepts and definitions adopted in this case study drew on elements of the overall vulnerability assessment method, as outlined and adopted in the: Guidelines for Developing a Climate Change Adaptation Plan and Undertaking an Integrated Climate Change Vulnerability Assessment; November 2012; Local Government Association of South Australia.

This method describes how likely exposure to climate scenarios, and sensitivity and adaptive capacity of assets to these climate changes, are used to assess the likely impact and vulnerability of assets to these changes. This process was developed by the Allen Consulting Group, 2005, and is based on that developed by the IPCC, 2007.

This broader conceptual framework is presented in Figure 5.

This approach generates an impact rating based on assessed asset sensitivity to different climate change exposure scenarios. The adaptive capacity of assets in relation to impacts is also assessed and used to assign asset vulnerability, where adaptive capacity relates to asset condition and context.

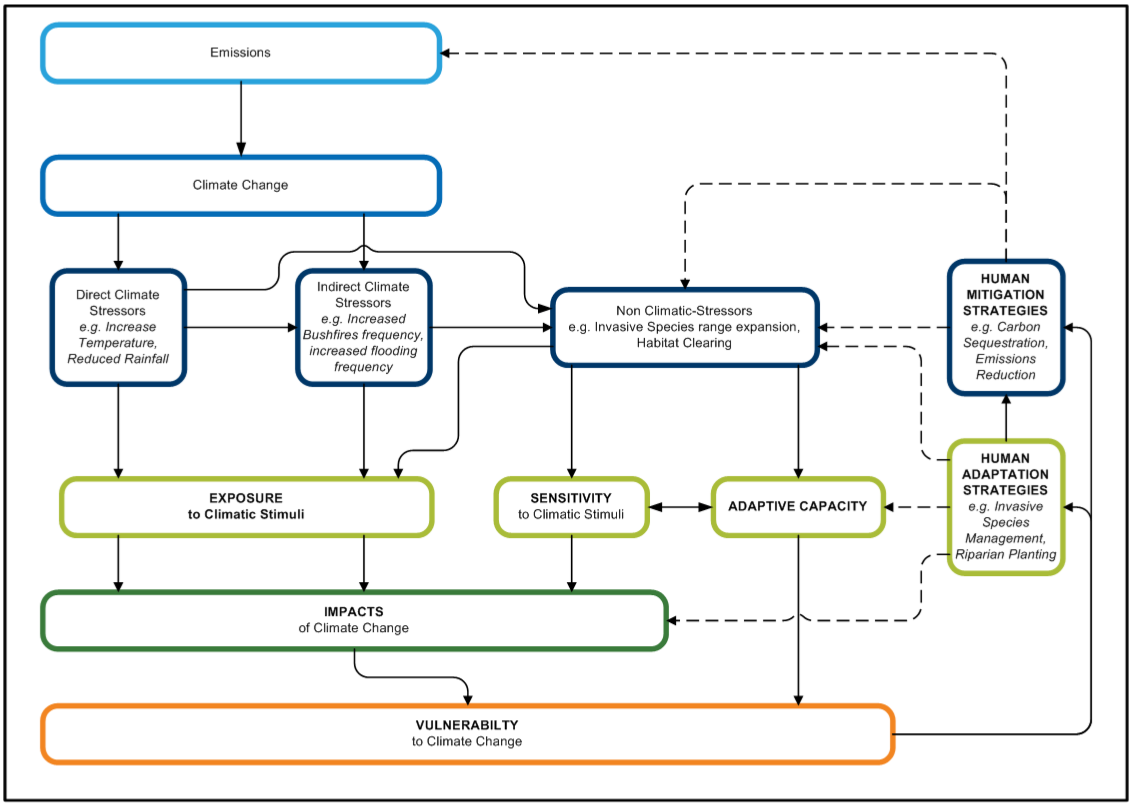

Figure 5. Conceptual framework for assessing vulnerability to climate change, showing relationships between exposure, sensitivity, impacts, adaptive capacity and vulnerability.

Solid lines indicate direct affective relationships between biophysical components (such as the impact of climate change on direct climate variables, or of non-climate variables on exposure to climatic variables). Dashed lines indicate the effects of human activity, including the impacts of climate change, and adaptation and mitigation activities. (Adapted from: Capon et al 2013).

Key definitions relating to this framework are below and are provided in Appendix 2 - Glossary:

Vulnerability

The term ‘vulnerability’ is used in many different ways by various research communities, such as those concerned with secure livelihoods, food security, natural hazards, disaster risk management, public health, global environmental change, and climate change (Fussel and Klein, 2006).

For the purposes of this study the following definition in Appendix 2 was adopted based on the 2001 IPCC Assessment Report (IPCC 2001).

Other Key Definitions

This study adopted the following definitions in Appendix 2 of exposure, sensitivity and adaptive capacity in an effort to achieve a consistent understanding and interpretation of the proposed framework. These definitions are based on those provided in “Guidelines for Developing a Climate Change Adaptation Plan and Undertaking an Integrated Climate Change Vulnerability Assessment; November 2012; Local Government Association of South Australia.” (Local Government Association of South Australia 2012)

Other Key Climate Impact Assessment Terms

Other key terms related to some of the key concepts are briefly described in Appendix 2 under Hazard, Impact and Risk.

Appendix 4: Application of Vulnerability Assessment Framework

Vulnerability Assessment Approach – Worked example for Open Space

This appendix presents a worked example for indicative vulnerability results for are area of open space. The results illustrate the detailed information assigned in the asset vulnerability assessment process to each asset depicted in the relevant spatial dataset.

Map views of the results for a section of a representative area of Melbourne are presented in Figure 6 to Figure 8. The views show the vulnerability rating assigned to individual open space for three scenarios comprising the 2030 2050 and 2070 results for the RCP 8.5. The views show how open space transition from lower to higher vulnerability ratings over time.

Green indicates a low vulnerability rating; yellow a moderate rating; and red a high rating. The factors determining the vulnerability rating of each open space include:

Exposure:

- High maximum temperatures
- Extreme heat days
- Heat waves
- Reduced rainfall
- Extreme rain events
- High wind

Sensitivity:

- Use or type of park
- Level of service
- Size (overall area)
- Size (variable to area metric)

Adaptive Capacity:

- Risk
- Proximity to water bodies
- Context to surrounding buildings (proximity)
- Context to roads (proximity to busier roads)
- Canopy and shrub bed layer coverage (% coverage)

The views show that the largest change appears to occur between 2030 and 2050.

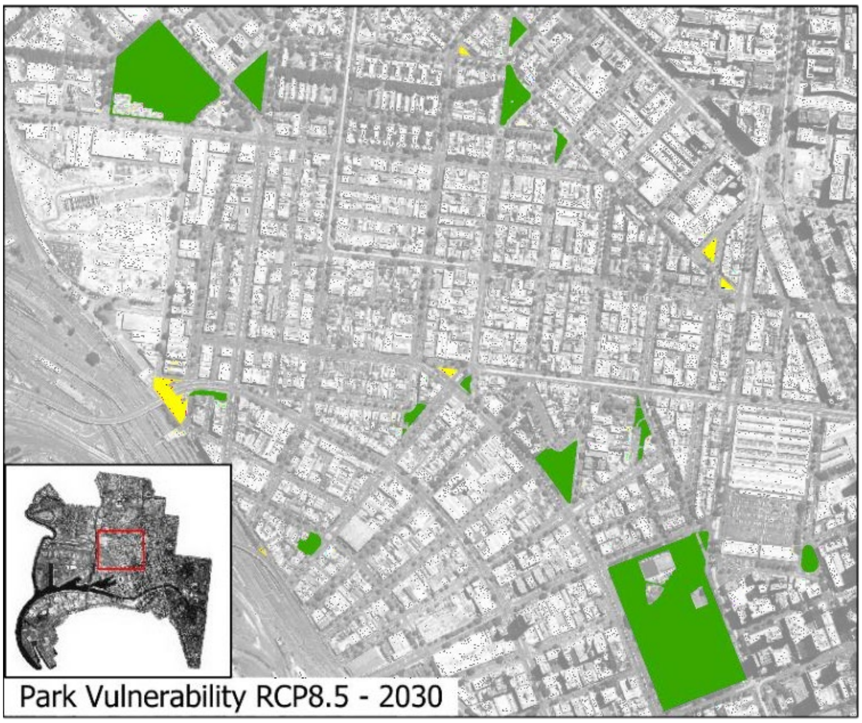

Figure 5. Open Space - Vulnerability ratings (2030 – RCP8.5) where green is low, red is high.

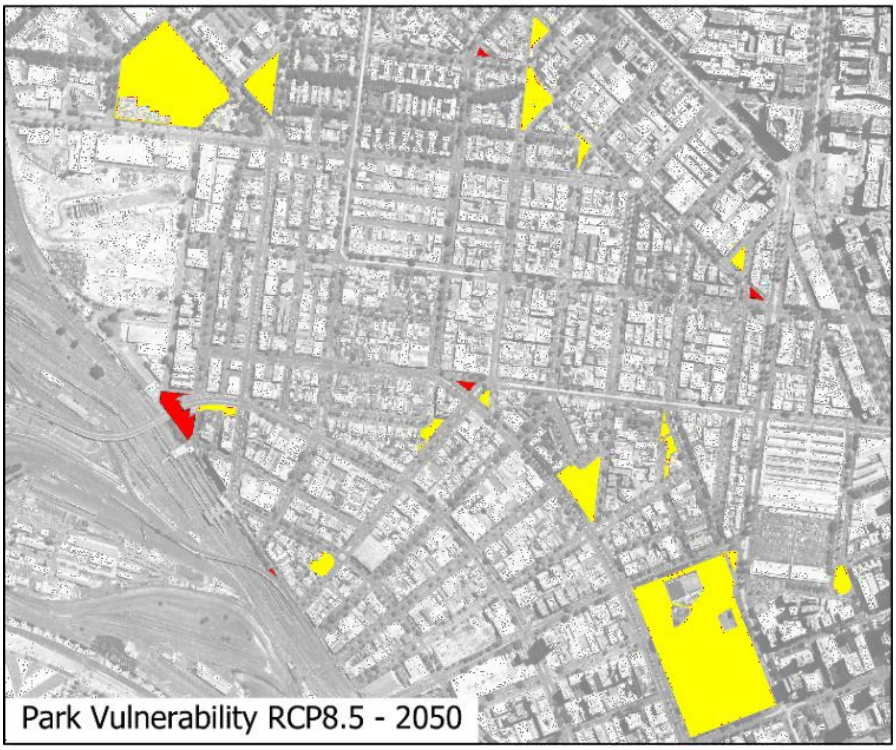

Figure 6. Open Space - Vulnerability ratings (2050 – RCP8.5) where green is low, red is high.

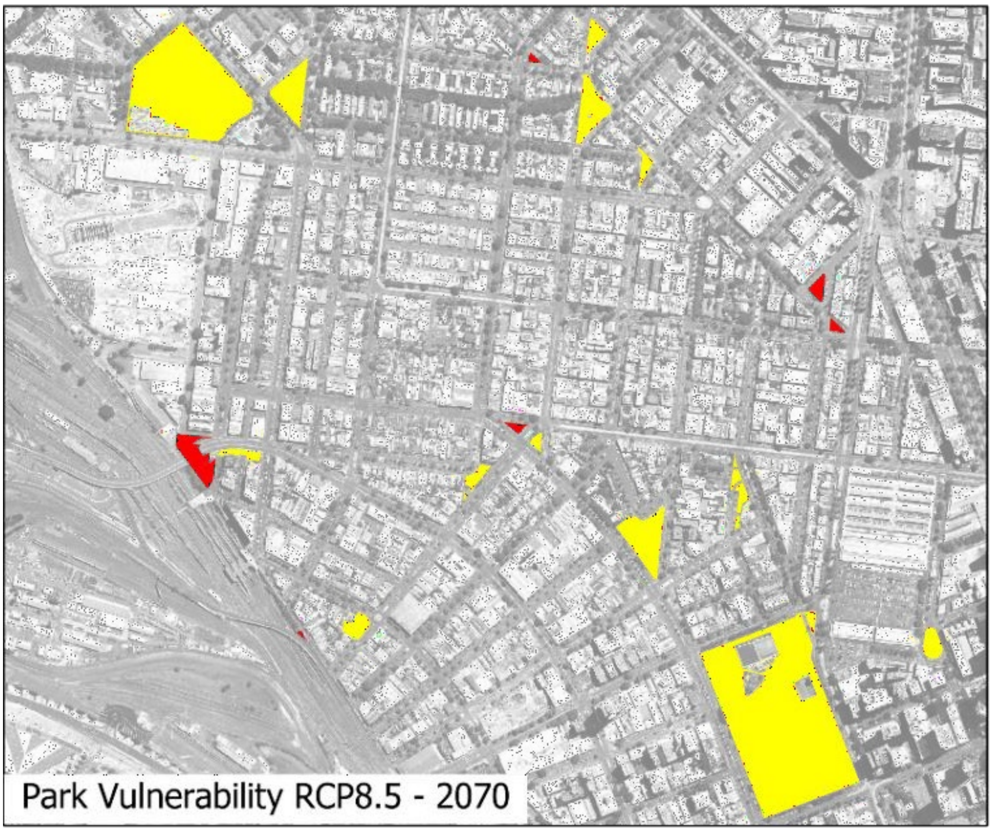

Figure 7. Open Space - Vulnerability ratings (2070 – RCP8.5) where green is low, red is high

Figure 9 shows how two open space areas that appear similar in size can score very differently based on their individual characteristics.

In the example presented, the open space area on the left and identified in red, is assessed to have a poorer level of service (since it is classified as a streetscape park) and less tree canopy than the open space area on the left (Asset ID 1747748) that is identified in yellow.

A summary of the open space area characteristics, as reflected in open space area dataset attributes, is presented in Table 8. This table identifies how:

- The driving factors for the difference in vulnerability rating for the two open space assets are:
  - The park category (which is reflects the level of service (LOS), where '5' indicates a poor service and high sensitivity, and '2' indicates a high level of service and lower sensitivity)
  - streetscape parks are less maintained than landscape parks (hence the LOS rating of 5 for the latter)
  - percentage cover of canopy and shrub beds (where the higher the value the lower the adaptive capacity). This is visually identifiable in the above maps, where Hawke & King Street reserve (Asset ID 1747748) contains large trees.
- Proximity to water bodies and proximity to busy roads (additional adaptive capacity ratings where the higher the value the lower the adaptive capacity) cancel each other

out.

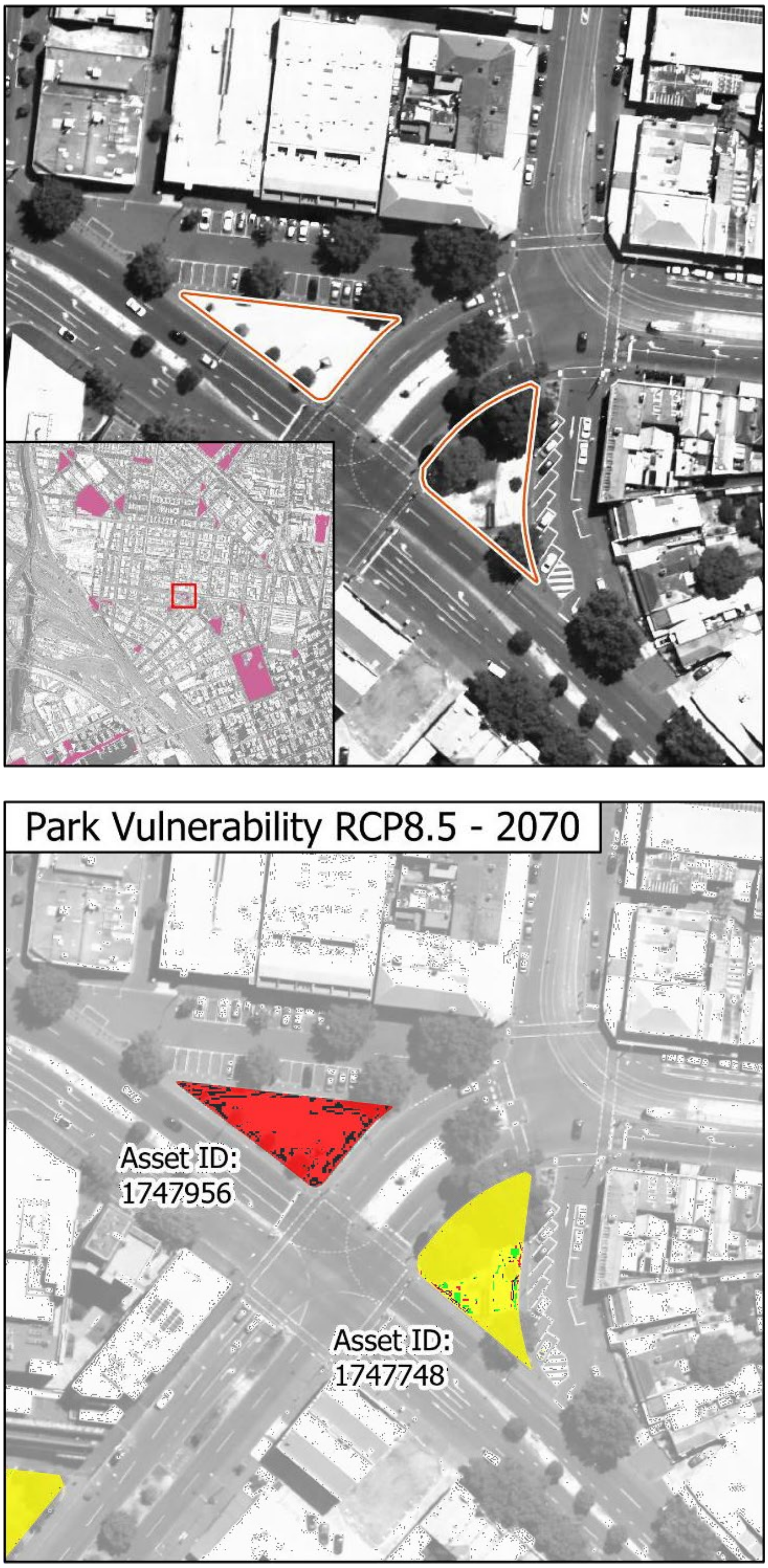

Figure 8. Open Space vulnerability example showing two open space area results (yellow is moderate, red is high).

Table 5. Factors affecting difference in vulnerability rating for two Open Space assets

	Asset ID	1747748	1747956
Asset Information	Property name	Hawke & King Street Reserve	King & Victoria Street Reserve
	Park category	Landscape Park	Streetscape
	Area of park	576.1	482.5
Exposure (combined)	Exposure (RCP8.5 2070)	4.17	4.17
Sensitivity	Sensitivity type	2	2
	Level of service	2	5
	Size (area)	5	5
	Size (perimeter to area)	3	3
	Overall Sensitivity	3	3.75
Impact	Impact (RCP8.5 2070)	12.5	15.6
Adaptive Capacity	Risk	1	1
	Proximity to water bodies	4	3
	Context to surrounding buildings (proximity)	4	4
	Context to roads (proximity to busier roads)	3	4
	Canopy and shrub bed layer coverage (% cover)	3	5
	Overall Adaptive Capacity	3	3.4
Vulnerability	Overall Vulnerability	37.5	53.125

Note: *Red - highlights values that are significantly different; yellow – identifies minor differences; blue - highlightsvalues that are the same.*
For sensitivity ratings the higher the value the greater the sensitivity.
For adaptive capacity ratings the higher the value the lower the adaptive capacity.

Appendix 5: LGA asset data collation and processing

(Final version of LGA asset data collation and processing document).

Spatial Vision