Hurstville Street Tree Management Study

Inventory, issues and future management

Prepared for
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Project Manager	Meredith Henderson (02) 8536 8671 Level 6, 299 Sussex Street, Sydney, NSW, 2000
Prepared by	John Gollan, Meredith Henderson, Chris Morris, Ashlee Clarke
Reviewed by	Beth Medway
Approved by	Beth Medway
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Abbreviations

Abbreviation	Description
csv	Comma separated value
ELA	Eco Logical Australia
GIS	Geographic Information System
GPS	Global positioning system
HCC	Hurstville City Council
KCC	Kogarah City Council
LGA	Local Government Area
SCC	Sydney City Council
SSC	Sutherland Shire Council
SULE	Safe Use Life Expectancy
WC	Waverley Council

Executive summary

Management of street trees is a major ongoing activity for local government and a detailed inventory of street trees is a first step in effective street tree management. Hurstville City Council (HCC) engaged Eco Logical Australia Pty Ltd (ELA) to conduct a street tree study in the HCC Local Government Area (LGA). The aims of the study were to document the street trees across the entire LGA and identify some key characteristics of those trees.

Putting together a street tree inventory can be a major challenge, especially for the large LGAs. To provide some context on the enormity of the task, for LGAs as large as Hurstville (~23 km^2), the nearby LGA of Kogarah (~19.5 km^2) took three years to produce a street tree inventory.

Following discussions with HCC, an additional aim was to establish a spatially explicit data set to form the basis of a street tree asset register. Such a data set would be able to integrate text and spatial data to be used in HCC corporate systems. Such data would allow a range of queries to be performed.

A series of characteristics for each street tree and its surrounds were selected to enable data collection. These characteristics included:

- genus and species
- common name
- location including latitude and longitude
- footpath material
- damage to footpath, and if any, the severity of damage
- presence of kerb and gutter
- damage to kerb and gutter, and if any, the severity of damage
- presence of overhead services, and if any, the type of service
- indication of tree health
- management recommendations.

To commence data collection, a base data layer was created for all the street trees in the LGA. High resolution aerial images were imported into GIS software. A cadastral layer showing streets with the nature strip/footpath area was used to separate out those trees that were considered street trees. A ‘place marker’ was positioned on the spatial layer where each tree occurred in the road / nature strip polygons. The place markers formed the basis of the initial spatial data set, as each tree had a unique identifier and set of spatial (X and Y) coordinates.

The spatial data was then extracted and tree characteristics for each place marker were collected in the field. Pilot testing with a mobile device (in this case an Apple iPad) and using a form function proved to be an inefficient means of data collection. An alternative, more effective method was developed which involved capturing the field data using a laptop in a moving vehicle. While the driver was responsible for navigation and surrounding safety, the passenger entered the data.

Prior to field work, there was an estimated 17,033 street trees in the LGA (i.e. the number of place markers). However, on completion of the field work, the number of street trees present in the LGA was reduced to 14,819. Across the whole of the LGA, 104 genera were encountered, and the most common were *Lophostemon confertus* and *Callistemon* sp. These made up nearly half (~48% of the total trees) of the trees across the LGA. Other common tree species included: *Eucalyptus microcorys* (~7%), *Melaleuca quinquenervia* (~6%), and *Tristaniopsis laurina* (~3%). While these same species tended to be the most common within each individual suburb, the proportions of each differed between suburbs.

Some trees were rarely encountered such as *Araucaria bidwillii* (one individual), *Koelreuteria elegans* (one individual), *Thevetia peruviana* (one individual), *Laurus nobilis* (three individuals) and *Omalanthus populifolius* (two individuals). These are not species generally used by councils as street trees so are likely to be planted by local residents.

Damage to hard pavement was low across approximately 85% of the LGA (where trees were adjacent to a hard pavement). Figures were similar with respect to damage to kerb and gutter, where there was only damage in around 15% of cases. Analyses within each suburb indicated that these proportions varied between suburbs.

The data on tree health showed that the majority of street trees in Hurstville are in good condition (~96% of total) and most (98% of total) were recommended to be retained. Only 4% were in a moderate or poor condition, and nine individuals were considered dead. A total of 320 were deemed to require immediate management such as pruning of deadwood, removing leaning branches to reduce canopy load, or complete removal due to pest or disease attack.

This study was successful in providing an inventory of the street trees across the Hurstville LGA. With each individual tree assigned a unique identifier with accurate geographic coordinates, and semi-quantitative data on damage to infrastructure, tree health and the presence of overhead services. The dataset will provide the basis for a valuable, powerful and useful tool for managing street trees in the Hurstville LGA. Given that the major hurdle has now been addressed and data are available electronically, an almost endless number of queries could be addressed. While this study has provided some of the more basic information that can be extracted (i.e. what is the most common street tree species in the Hurstville LGA), queries can now be tailored to meet the specific needs of HCC.

Importantly, and to maintain the dataset's value, the data should not be view as 'static'. Instead, the data will require periodic updating to maintain validity.

1 Introduction

1.1 Overview of values and issues

Street trees, loosely defined as '*trees lining municipal streets'*, are a common sight of urban landscapes (**Figure 1**). The main purpose of street trees is to provide aesthetic values for the community; softening what otherwise would be labelled 'a concrete jungle'. In some cases, street trees can also have cultural and heritage significance. While these are perhaps the traditional views of their purpose and value, recent thinking shows that street trees have more to offer.

First, street trees can reduce the urban heat island effect by reducing temperatures through evaporative cooling and shading surfaces from the sun's rays (Kurn et al. 1994). Second, street trees are being valued for their contribution to biodiversity, providing shelter, nesting sites and food sources for a range of native fauna (**Figure 2**). Third, there may also be fiscal benefits because higher housing prices are often associated with the 'leafier' suburbs (see article by Frew 2013). And finally, as the world becomes more aware of rising global temperature due to greenhouse gas emissions, street trees could provide a worthwhile mechanism for carbon sequestration and storage.

While the benefits of street trees are many, street trees also have their disadvantages. Street trees require ongoing management because they can cause a number of problems for residents and the authorities responsible for managing the trees. Extensive root systems can damage below ground infrastructure and crack and uplift surrounding pavements (**Figure 3**). Above ground infrastructure such as high voltage transmission wires can also be damaged by a tree's branches and trunk. Limbs, or even the entire tree, can fall due to high winds, disease, insect attack, or natural senescence. All of these problems pose a potential risk to public safety, and so it is important for authorities to respond accordingly – ideally before a tree causes a problem.

The response to an issue regarding a street tree will depend on a number of factors, but whatever that response, a detailed inventory of street trees is a first step in effective street tree management. While conducting an inventory might seem a simple task, there are a number of challenges that need to be overcome.

Figure 1: Street trees - a common part of the urban landscape

Figure 2: Street trees provide resources for native fauna like this Black Glossy Cockatoo

Figure 3: Street trees can cause damage to surrounding pavement and infrastructure

1.2 Project scope

Hurstville City Council (HCC) commissioned Eco Logical Australia to prepare a Street Tree Management Study. The purpose was to maximise HCC's sustainable urban forest canopy across the local government area (LGA).

In managing street trees, HCC has traditionally used street addresses to locate and reference individual trees. A hand-drawn 'paper map' from 1991 of trees in the LGA was a useful resource for street tree management (HCC unpubl. data). However, these approaches have had their limitations and drawbacks, in particular, data on individual trees were not available in digital format, and not easily and readily able to be updated. The consequences of these limitations are that data interrogation is virtually impossible and decision making is often based on out-dated information. In addition to these data limitations, the challenge of hardcopy or paper based data is that it can be difficult to respond to community concerns in a customer friendly time frame.

With the advancement of easy to use asset management software, portability of data capture devices (e.g. handheld GPS units and 'tablet' computers), availability of high resolution satellite imagery and free online mapping resources, up-to-date and readily manipulated data on individual trees are achievable. These elements when combined can provide HCC with a valuable asset management system.

At the outset of the project, HCC wanted ways to:

- track individual trees across the entire LGA
- integrate text and geospatial data on each tree.

To achieve this, the study aimed to provide:

- detailed and accurate baseline data about the existing street trees throughout the LGA
- digital tools to update the baseline data in the future.

This report presents how these objectives were achieved through:

- an outline of the approaches used
- justifications for the approach
- a broad overview of results of the street tree inventory
- offering suggestions on how the data might be used

2 Methods

2.1 Definitions adopted

For the purposes of this project, we defined a street tree as any tree that grew in the public right of way. These trees may, or may not have been planted deliberately. The public right of way included all footpath areas (area between boundary of private property and road edge), median strips, traffic islands and roundabouts. However, parkland, bushland reserves or other public spaces (e.g. shopping plazas) were excluded.

The definition of a 'tree' was also important to describe because what is meant by 'a tree' can vary among different people and organisations. For this study we considered a tree to be any species with a natural growth habitat with a single upright trunk and canopy (**Figure 4**). Thus, when collecting field data, we considered newly planted species which may have been less than 1 m in height as 'street trees'.

Figure 4: Trees were defined as a species with a growth habit with a single upright trunk and canopy (Image source: http://www.ext.colostate.edu/mg/gardennotes/121.html)

2.2 Approach

Our study combined several stages, which are described in detail below. The stages consisted of:

1. information review and gap analysis
2. development of data capture tool and database framework
3. desktop GIS assessment
4. field survey.

2.3 Information review and gap analysis

A number of contemporary and publicly available local council tree or bushland management plans and guiding documents were reviewed to determine if and how other councils managed street trees. If the councils did manage street trees, how did they achieve this and what information did they require to achieve their goals? We also wanted to understand how this information was presented to the public. Councils researched were:

- Kogarah City
- Rockdale City
- Waverley
- Sutherland Shire
- Sydney City.

Aspirations for most of the local government areas researched were to:

- improve the urban forest
- increase the canopy cover in the LGA
- provide guidance or clear policy statements to resolve conflict around tree and vegetation management in the LGA.

2.3.1 Kogarah Council Street Tree Strategy and Masterplan (undated)

Kogarah City LGA states that they have 12,000 street trees to manage. The strategy and management plan for this LGA was based on the digital data set that had already been established. The strategy document is large and comprises many procedures and guidelines, an analysis of legislation, detailed specifications for planting and equipment required. The document outlines the character precincts present in the LGA and aligns the street tree characters to these precincts.

This strategy document is broad ranging and was based on a data audit from an existing data set of species, their condition and location. It is worth noting that Kogarah Council spent three years collecting the data supporting their management plan. A street tree strategy and masterplan document similar to that of Kogarah Council would be possible once HCC has the data in place.

2.3.2 Rockdale City Council

Rockdale City Council did not have a specific street tree management strategy, masterplan or guiding document. Rather, the Council had a biodiversity strategy that includes principles for management of biodiversity in the LGA. It is unclear from the available documents how this Council specifically manages street trees and whether there is a plan to develop a strategy or masterplan for street trees.

2.3.3 Waverley Council Tree Management Plan (2007)

The Waverley Council plan treated tree management in a holistic manner by integrating street tree issues with trees in parks and on private land. The plan was developed after a comprehensive review of tree management issues in the LGA and community consultation. Issues identified by the community drove the aspirations in the plan. It was also guided by the *2003 Urban Forest Policy* developed by the NSW Local Government Association.

The plan aimed to provide a framework for the management of all trees in the LGA over a period of ten years. The plan outlined a number of strategies and actions to achieve them. For example, ensuring optimal target percentage canopy covers informed strategic planning for tree planting in the LGA. A number of targets were developed to guide future planning for the management of trees, including street trees in the LGA.

Strategies relating to street trees ranged from high level planning strategies to operational guidance and included:

- Adopt the tree selection process indicated in Statewide's Best Practice Manual, *Tree Selection Process* and establish a list of options to address root control and damage to property and make it available to key personnel.
- Use the Waverley Street Tree Database as an active and informative planning tool for managing trees in Waverley.
- Initiate the policy and procedures for claims for damage as provided in the tree management plan.

- Identify trees with a Safe Useful Life Expectancy (SULE) of five years or less and assess on an individual basis for possible replacement.
- Implement measures to ensure adequate community consultation regarding tree removal/replacement programs.
- Implement policies for height, directional pruning, identification of opportunities for ‘pseudo’ street trees, ABC works and relocation of services. Consider alternative solutions for street tree planting.
- Implement procedures to ensure informed species selection, best practice in tree planting and maintenance and general public support for tree planting programs.

2.3.4 Sutherland Shire Council Urban Tree and Bushland Policy (2011)

Sutherland Shire Council’s (SSC) document aimed to integrate management of trees and bushland across the LGA on both private and public land. The policy treated trees and bushland in a wholistic and consistent manner across the LGA. Similar to the approach adopted by Waverley Council, the SSC document provided a framework for developing further plans for implementation of the policy.

The policy section relevant to street trees is a one page statement of intent, list of council commitments and call to action for residents. The Council committed to:

- Maintaining street trees to manage known risk to life, property and infrastructure.
- Actively planting street trees to ensure that there is no net loss of tree canopy.
- Undertaking best practice pruning of street trees.
- Giving priority to street tree planting in areas of greatest ecological benefit or visual amenity.
- Planting indigenous trees appropriate to the environmental setting.
- Planting indigenous trees in conjunction with Council works.
- Selecting species that are less likely to cause problems with branch loss, root damage to footpaths and avoid conflict with overhead power lines.
- Providing tailored street tree species list for the Sutherland Shire, made available to staff and the community through Shire Maps.
- Requiring street trees to be planted as part of the redevelopment of properties.

There is an implementation strategy for the maintenance and planting of street trees that is worth inspecting.

2.3.5 City of Sydney Urban Forest Strategy (2013)

This strategy aimed to plan for and manage trees and vegetation across the LGA regardless of tenure. The key drivers for this strategy were to protect and maintain the existing urban forest and increase canopy coverage. This document provided a mechanism to support a fundamental shift in the way that not only the Council, but the community view and manage trees and vegetation. The shift describes a move away from traditional single species / individual view to a more wholistic view of urban vegetation as critical infrastructure. While some of the aspirations and drivers are similar to the other Councils, Sydney’s approach and language is vastly different.

The strategy has four key objectives:

- protect and maintain existing urban forest
- increase canopy cover
- improve urban forest diversity, and
- increase community knowledge and engagement.

The strategy does not single out management of street trees. Street tree management and planning is guided by the Street Tree Masterplan (2011).

2.3.6 City of Sydney Street Tree Masterplan (2011)

The Masterplan was part of a suite of documents developed to manage street trees in the LGA. The Masterplan specifically aimed to:

- Direct the most appropriate species and planting techniques for the many potential tree sites in Sydney - ' the right tree for the right location'.
- Establish a street tree species palette suited to the environmental conditions of the City of Sydney's public realm.
- Reinforce and enhance the special characteristics of city precincts using distinct street tree planting.
- Increase the number of trees and canopy coverage in Sydney's streets.
- Establish green city corridors by providing high quality street trees.
- Improve street tree establishment and survival rates.
- Guide the maintenance and management of existing and new trees to ensure that they survive and thrive in the harsh urban conditions.
- Provide clear guidelines to ensure a consistent approach towards the provision of street trees in the City of Sydney.

The document outlined in detail the requirements for each planting precinct. Each precinct was presented as spatial and textual information. Precincts were based on suburbs and not zoning. Precinct plans were short documents outlining the objectives, ecological and environmental attributes, current dominant species and future planting palettes. Species palettes were applied spatially and shown on precinct maps.

2.3.7 Gaps for Hurstville City Council

Hurstville City Council has not developed documentation to manage urban vegetation or street trees. One of the few existing documents was a hand drawn street tree ‘masterplan’ from 1991 (HCC unpubl. data). This masterplan was a depiction of the current species found along the streets of the LGA. There was no guidance on the future requirements or targets for the trees.

It was clear that other councils had invested significantly in the data collection and development of documents to support street tree management. Discussions with HCC indicated that some project team members wanted precinct plans in the vein of Sydney City Council, whereas others preferred to have standards and guidelines developed in the vein of Kogarah City Council. To develop any of these documents, it was clear that HCC needed to invest in obtaining spatial and textual data upon which to build.

2.4 Development of data capture tool and database framework

ELA met with HCC project team staff to discuss the desired set of street tree characteristics to collect as part of the field work. ELA also looked at the requirements of the project brief, and developed a list of characteristics and the data categories that related to those characteristics.

The set of characteristics had to be able to form the basis of a data set to be incorporated into the HCC corporate text-based databases as well as inform spatial data sets. ELA aimed to establish a simple spreadsheet that could be extracted as a 'csv' (comma separated value) file and imported into the corporate systems regardless of operating system. Discussions with HCC revealed that a csv file could be used and that this was the preferred method for importing data.

The set of characters or attributes can be found in the first column of **Table 1**. Some of the attributes were generated during the desktop assessment. However the bulk of the attributes were collected in the field. Data was mostly categorical data. Categories or ranges of variables are listed in **Table 1**.

Once the categories were agreed to with HCC, the data table was set up for use on a mobile tablet. In this case ELA chose to use an Apple iPad. A form was created and coupled to a spatial application (see **2.6.1.1** for more information). This would allow field data capture direct into the data sheets. These data sheets were then exported as a csv file and used in ESRI spatial software.

2.5 Desktop GIS assessment

The street trees were digitised on ArcGIS 10.2 using high-resolution aerial imagery. Given the definition of street tree adopted (see **Section 2.1**), the trees in parks, reserves or on private property had to be excluded spatially. The HCC road spatial data set was used to intersect with the aerial images.

High resolution aerial imagery and the roads layer were supplied by HCC. The aerial imagery was SKM Aerial Imagery captured in January 2011. Google Earth imagery was used in some areas where the imagery was not clear.

The trunk of the tree was assumed to be in the centre of the canopy, unless a lean was obvious. If the trunk appeared to be within the council road reserve, this tree was marked as a point, as seen in **Figure** 5. All marked trees within the roads land area were given a unique identification number. Mapping grid coordinates, suburb name, nearest house number and the name of the road were calculated using the join function within ArcGIS 10.2.

By providing both coordinates and house number and street name closest to each tree, HCC can continue using their current identification of street trees or use the more spatially explicit coordinates. Coordinates can be exported to mobile geographical positioning systems for use in a range of tools (e.g. mobile computer tablets, directional GPS).

The layer containing the unique identifier and location information was then exported as a csv file. The csv file can be used in a range of software including Microsoft Excel and many geographical information systems.

Table 1: Summary of approach

Attribute	Method of acquisition	Range of variables	Comment
ID number	Desktop assessment	As determined by number of trees identified	Provides a unique identifier for each street tree
Address including house number, suburb and nearest cross street	Desktop assessment	As identified using the 'nearest function' tool in ArcGIS	Not always accurate or sensible (e.g. a tree adjacent to a park will not have a house number)
Coordinates (Latitude and Longitude)	Desktop assessment and Field	As determined by geographic spread of Hurstville LGA	Coordinates determined for trees using satellite imagery. 'New' trees i.e. planted after image acquired determined using a handheld GPS. Coordinates are expected to have an error of up to 10 metres in either direction.
Memo	Desktop assessment and Field	Google Street View, or Field collected	Specifies how data attributes (i.e. those below) were collected
Genus and species	Field	As identified by observers	Not always possible
Location	Field	Footpath/Nature strip Median strip/traffic island Raised bed/garden box Carpark	Described the general locality of the street tree
Pavement/Surrounding material	Field	Asphalt Concrete Grass Gravel Pebbles Pavers Mulch/Leaf Litter, or Dirt	Described the pavement material where the street tree grew or was adjacent*
Severity of damage to pavement/surrounding material	Field	None Minor	

Attribute	Method of acquisition	Range of variables	Comment
		Moderate Severe	
Presence of kerb and gutter	Field	Yes No	Described if a kerb and gutter was adjacent* to the street tree.
Severity of damage to kerb and gutter	Field	None Minor Moderate Severe	Described the degree of damage to the kerb and gutter (if present) that was closest to the street tree
Distance to road	Field	a = within 1m; b = between 1 and 3 m; c = greater than 3 m	Described the distance (based on the 3 categories 'a', 'b' and 'c') of the tree to the nearest residential driveway.
Presence of overhead wires and type	Field	None abc†, mains service Yes††	Described the type of wire infrastructure and whether the street tree would likely to impinge on the wires
Health	Field	Good, Moderate, Poor, Dead	Described the overall health of the tree
Management	Field	Prune Remove Retain	Based on the health of the tree (as above), made a recommendation on action
Comment	Field	As made by observer	Justification for the recommended management action (as above)

*'adjacent' was considered to be within a distance of 5 metres or less; †abc = aerial bundle cable; ††'Yes' was used initially and the type of infrastructure only included after day 3 of data collection.

Figure 5: Screenshot of digitised trees within ArcGIS10.2. Only trees with trunks within Hurstville Roads layer where marked. Trees are marked with a green dot.

2.6 Field survey

2.6.1 Pilot methods of data capture

Following the desktop assessment and before the final field data collection methodology was adopted (outlined in **2.6.2**), three approaches to capture the field data were piloted. Each of these is briefly outlined below.

Direct entry to customised database with Apple iPad

In the initial scoping stages of the project, it was envisaged that field data would be captured using an Apple iPad and directly imported to *iGIS*, a freely available software program available on the iTunes store (https://itunes.apple.com/au/app/igis/id338967404?mt=8). This software was considered ideal because it has been specifically designed as an asset management tool allowing customised forms (i.e. a database ‘front end’) to be made where attributes can be entered directly to the database ‘backend’. iGIS also has file formats (e.g. ‘.shp’) that allow easy exchange between ESRI’s ArcMap (used in Task 3), and provides mapping capabilities through the Google Earth mapping service.

But while this software was ideal for the task, it was found that entering data on the device itself was extremely cumbersome. Text fields were often touched inadvertently, there was a time delay every time the keyboard was needed to be displayed, and there was no ‘predictive text’ functionality. The latter caused slow data entry speeds because text has to be entered each and every time – even after the same words/phrase had been entered on several occasions.

While we investigated ways around these issues e.g. using single letter codes for certain phrases, data entry continued to be laborious. During an initial trial using the method of data capture, full entries for only 30 trees were complete in around two hours. This was an unacceptable rate of data acquisition and was abandoned as the means of collecting field data.

Data collection using a video camera from a moving vehicle

Data acquisition was trialled using a video camera mounted to the dashboard of a moving vehicle. This idea was akin the method of data acquisition that Google uses in their 'Street View' platform, or those used by sophisticated asset requisition systems (e.g. http://www.ptgrey.com/360-degree-spherical-camera-systems).

It was thought that an inexpensive digital video camera with GPS capability (we used a *Sony HDR-AS30V HD POV Action Camcorder*) could be advantageous if the required data could be collected more efficiently than having observers having to visit each individual tree. Video footage, for example would not only provide an objective historical record of street trees, but there would also be opportunity to gather data on the wider surrounds at a later date e.g. the era of buildings in a particular area, street signage condition etc.

On review of the footage captured (a total of three streets) the attributes of interest were often not discernible due to poor image quality at times (it was thought that vibration was a significant factor in this), and obstructed views of the trees. Even while this method allowed ground to be covered quickly, it was thought that each street would likely have to be driven twice in order to capture trees on both sides of a street. Furthermore, data would still need to be entered manually after extensive hours of reviewing video footage. It was concluded that the benefits of this method did not outweigh the costs, and so was subsequently abandoned.

Data collection using Google Street View

Data acquisition was also trialled using Google's Street View platform using Google Earth software. A .kmz file showing 'marker points' was created (i.e. marker points represented individual trees and linked to the unique identifiers during the desktop GIS assessment) and each tree was viewed on a desktop computer (**Figure 6**). Data were entered to a spread sheet. In some cases this method showed promise, for example where the image was current, of good resolution and the identification of the species was readily determined (e.g. **Figure 6**). However, in other cases, collecting details on the required attributes was problematic due to parked cars (**Figure 7**) or imagery was several years old. This method was abandoned as a main method of data acquisition, but was used in some instances (more detail in **2.8**). The final dataset contains a field 'Memo' which demarcates the trees where data was collected using this method.

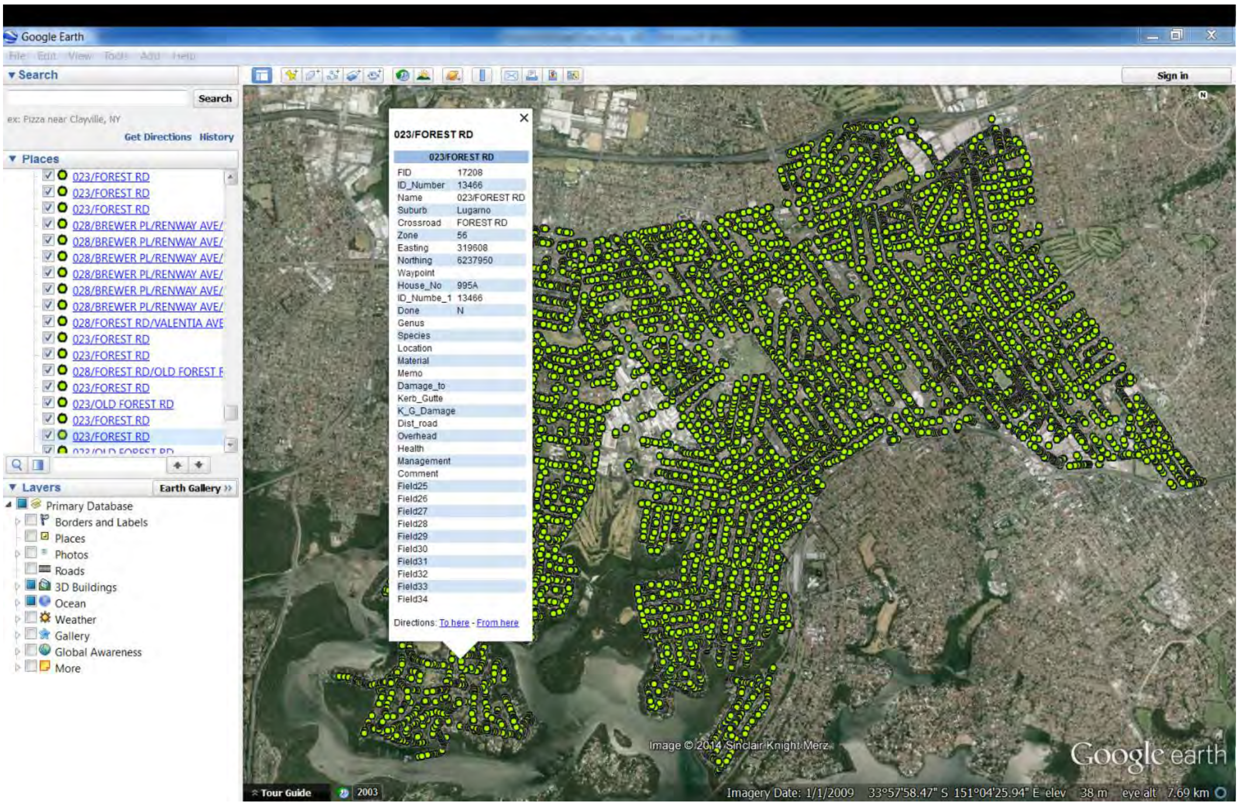


Figure 6: Screen shot of Google Earth showing green dots (marker points) that represented individual trees and linked to a unique identifier. Inset shows an example of the attributes assigned to each marker point during the desktop assessment.

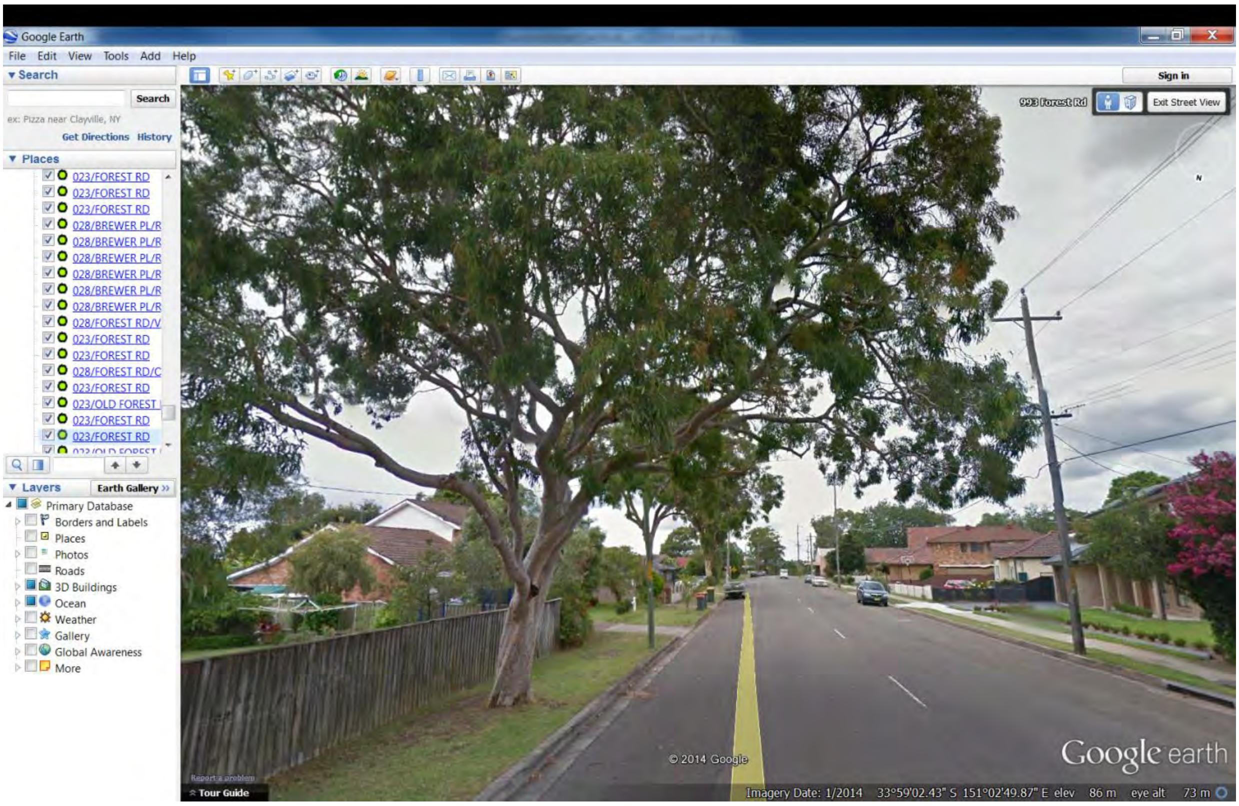


Figure 7: Screen shot of Google Street View of the marker point highlighted in Figure 6

Figure 8: Example of parked cars obscuring the footpath and kerb and gutter

2.6.2 Data entry to customised Microsoft Excel spread sheet using laptop computer

The final approach trialled, and subsequently implemented for field data capture, was to inspect individual street trees (as identified in the desktop assessment) and enter data directly to a Microsoft Excel spread sheet using a laptop computer. The spread sheet was constructed with unique rows (representing individual street trees identified in Task 3) and columns (representing the attributes to collect for each street tree; **Figure 15**). The following section provides the general principles adopted, justifies particular aspects, and details the overall approach used.

General principles and approach to data collection

At the beginning of the data collection stage, it was decided (and in consultation with HCC) that all observations would be limited to the same two people. This would ensure consistency in the variables collected. All assessments were made by ELA ecologist, John Gollan, or ELA arborist, Chris Morris.

To further ensure data consistency, quality and repeatability, assessments for some variables were also calibrated between the two observers. Here we used the principles of the *Delphi Method* (Linstone and Turoff 1975), which involved each observer making an independent assessment for a particular variable, and not revealing ones assessment until all observations were complete.

After completion, assessments were revealed to the other and discussion was had on the reasons why they provided particular judgment. Where there was disagreement, each observer revised their answers in light of the discussion until an agreement could be reached.

Under the *Delphi Method*, it is believed that during this process of discussion and revision, the range of the answers will decrease and the assessors will converge towards the one "correct" answer. This type of calibration was especially important for those attributes that were somewhat subjective i.e. the degree of damage to the kerb and footpath, and the health of the tree.

Table 2 shows the definition of severity classes for attributes where relevant. **Figure 9** to **Figure 14** shows examples to help illustrate the definitions.

Table 2: Attributes collected, the range of values used and the definition used to guide the assessment

Attribute	Range of variables	Definition
Damage to pavement/surrounding material	None	No observable damage
	Minor	Surface cracking but with no discernable displacement of damaged portion(s)
	Moderate	Some surface cracking with displacement of damaged portion(s) not exceeding 20mm
	Severe	Extensive surface cracking with displacement of damaged portion(s) greater than 20mm
Damage to kerb and gutter	None	No observable damage
	Minor	Some surface cracking of kerb and/or gutter but with no discernable displacement of damaged portion(s)
	Moderate	Some surface cracking of kerb and/or gutter and with displacement of damaged portion(s) not exceeding 20mm
	Severe	Extensive surface cracking of kerb and/or gutter (i.e. in more than four places), and with displacement of damaged portion(s) greater than 20mm
Health	Good	No obvious pest or disease issues and so appeared to be in good health
	Moderate	Pest or disease issue likely e.g. die back of a limb, foliage weakly discoloured, insect attack to foliage or wilting
	Poor	Pest or disease issue highly likely or observable e.g. die back of several limbs, foliage strongly discoloured, extensive insect attack to foliage, wilting of tree or bracket fungi present
	Dead	Tree dead or most likely dead
Management	Prune, Remove, or Retain	Tree health would likely benefit from pruning dead, dying or damaged limbs.
		Tree should be removed due to death, severe disease, poor health or potential to be dangerous to public†
		Preserve tree as there was no observable management issues

†a comment was added to the spread sheet to indicate the justification for removal

Figure 9: Example of kerb and gutter regarded with 'Moderate' damage. This damage category was defined as having "Some surface cracking with displacement of damaged portion(s) not exceeding 20mm".

Figure 10: Example of kerb and gutter regarded with 'Severe' damage. This damage category was defined as having "Extensive surface cracking with displacement of damaged portion(s) greater than 20mm".

Figure 11: Example of pavement/surrounding material with 'moderate' damage. This damage category was defined as having "Some surface cracking with displacement of damaged portion(s) not exceeding 20mm".

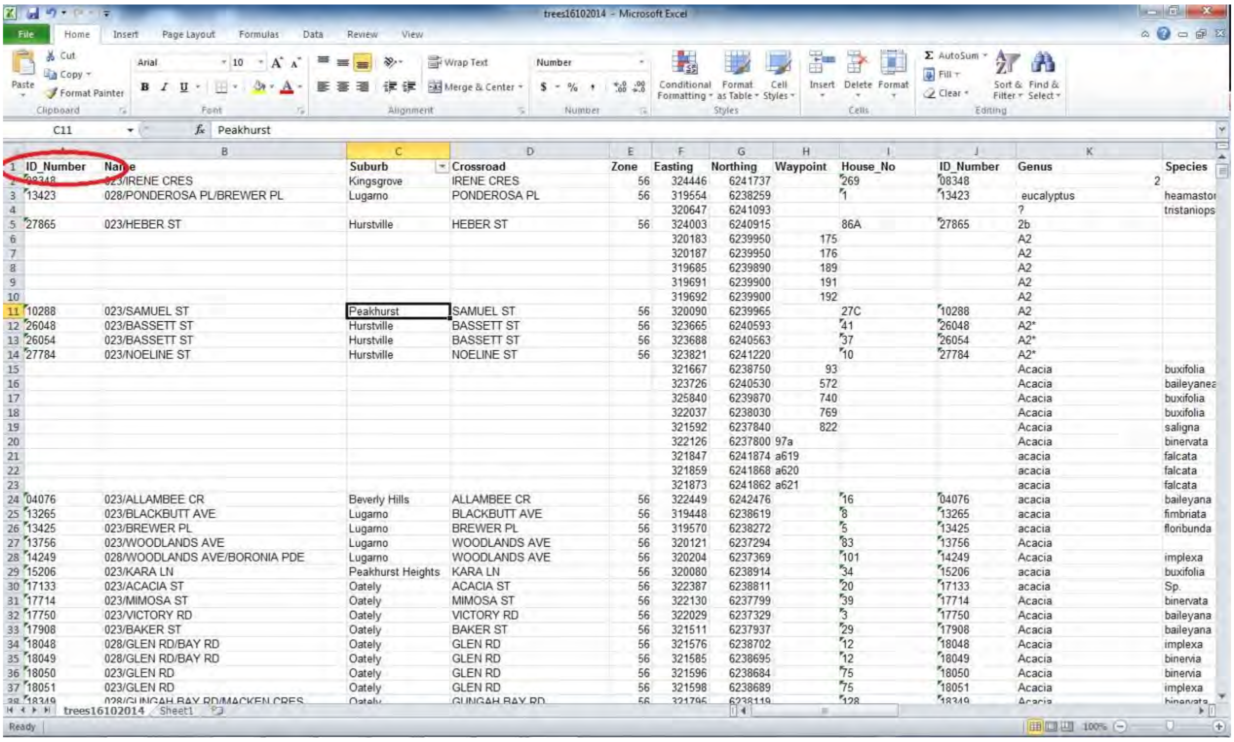
Figure 12: Example of pavement/surrounding material with 'severe' damage. This damage category was defined as having "Extensive surface cracking with displacement of damaged portion(s) greater than 20mm".

Figure 13: Trees that were assigned as having 'poor' health showed signs of pest or diseases such as this bracket fungus.

Figure 14: 'Pruning' was recommended where it was thought that the tree health could be improved. These trees often had dead, dying or damaged branches as illustrated here.

When severity ratings for attributes were determined and consistency between observers was deemed satisfactory, field data were then collected by both observers from a slow moving or stationary vehicle. Both observers would make assessments – trees on the left usually made by the passenger and trees on the right by the driver. The passenger entered all data using a laptop computer.

In some cases, for example where trees were obscured by parked cars or where it was unsafe to stop the vehicle, an observer would leave the vehicle to make the assessment. Where trees were not identified in the desktop assessment, new entries were added (inserting a new row) and geographic coordinates were added using a handheld GPS.



	ID_Number	Name	Suburb	Crossroad	Zone	Easting	Northing	Waypoint	House_No	ID_Number	Genus	Species
2	08348	023/IRENE CRES	Kingsgrove	IRENE CRES	56	324446	6241737		269	08348	2	
3	13423	028/PONDEROSA PL/BREWER PL	Lugarno	PONDEROSA PL	56	319554	6238259		1	13423	eucalyptus	heamastor
4						320647	6241093				?	tristaniops
5	27865	023/HEBER ST	Hurstville	HEBER ST	56	324003	6240915		86A	27865	2b	
6						320183	6239950	175			A2	
7						320187	6239950	176			A2	
8						319685	6239890	189			A2	
9						319691	6239900	191			A2	
10						319692	6239900	192			A2	
11	10288	023/SAMUEL ST	Peakhurst	SAMUEL ST	56	320090	6239965		27C	10288	A2	
12	26048	023/BASSETT ST	Hurstville	BASSETT ST	56	323665	6240593		41	26048	A2*	
13	26054	023/BASSETT ST	Hurstville	BASSETT ST	56	323688	6240563		37	26054	A2*	
14	27784	023/NOELINE ST	Hurstville	NOELINE ST	56	323821	6241220		10	27784	A2*	
15						321667	6238750	93			Acacia	buxifolia
16						323726	6240530	572			Acacia	baileyanea
17						325840	6239870	740			Acacia	buxifolia
18						322037	6238030	769			Acacia	buxifolia
19						321592	6237840	822			Acacia	saligna
20						322126	6237800	97a			Acacia	binervata
21						321847	6241874	a619			acacia	falcata
22						321859	6241868	a620			acacia	falcata
23						321873	6241862	a621			acacia	falcata
24	04076	023/ALLAMBEE CR	Beverly Hills	ALLAMBEE CR	56	322449	6242476		16	04076	acacia	baileyana
25	13265	023/BLACKBUTT AVE	Lugarno	BLACKBUTT AVE	56	319448	6238619		8	13265	acacia	fimbriata
26	13425	023/BREWER PL	Lugarno	BREWER PL	56	319570	6238272		5	13425	acacia	floribunda
27	13756	023/WOODLANDS AVE	Lugarno	WOODLANDS AVE	56	320121	6237294		83	13756	Acacia	
28	14249	028/WOODLANDS AVE/BORONIA PDE	Lugarno	WOODLANDS AVE	56	320204	6237369		101	14249	Acacia	implexa
29	15206	023/KARA LN	Peakhurst Heights	KARA LN	56	320080	6238914		34	15206	acacia	buxifolia
30	17133	023/ACACIA ST	Oately	ACACIA ST	56	322387	6238811		20	17133	acacia	Sp.
31	17714	023/MIMOSA ST	Oately	MIMOSA ST	56	322130	6237799		39	17714	Acacia	binervata
32	17750	023/VICTORY RD	Oately	VICTORY RD	56	322029	6237329		3	17750	Acacia	baileyana
33	17908	023/BAKER ST	Oately	BAKER ST	56	321511	6237937		29	17908	Acacia	baileyana
34	18048	028/GLEN RD/BAY RD	Oately	GLEN RD	56	321576	6238702		12	18048	Acacia	implexa
35	18049	028/GLEN RD/BAY RD	Oately	GLEN RD	56	321585	6238695		12	18049	Acacia	binervia
36	18050	023/GLEN RD	Oately	GLEN RD	56	321596	6238684		75	18050	Acacia	binervia
37	18051	023/GLEN RD	Oately	GLEN RD	56	321598	6238689		75	18051	Acacia	implexa
38	18349	028/GUNGAH BAY RD/MACKEN CRES	Oately	GUNGAH BAY RD	56	321795	6238119		128	18349	Acacia	binervata

Figure 15: Each row in the Microsoft Excel spread sheet represented an individual street tree, each of which was assigned a unique identification number (ID_Number circled in red). Columns represented attributes collected during Desktop GIS assessment (Task 3) or field collection.

2.7 Querying the data

At the outset of the project it was envisaged that the data fields chosen (see **Table 1**) would form the foundations for a database that would allow Hurstville Council managers to interrogate the data to answer questions and address management needs most relevant to them. With this in mind we put together a number of questions to demonstrate some of the trends apparent across the entire LGA and within individual suburbs. Questions posed of the data were:

- What are the most common species?
- What proportion of damage is there to hard pavements (footpaths only) and kerb and gutter?
- What is the health status of trees?

2.8 Data limitations, considerations and constraints

It is important to note that the data set should be considered a dynamic one i.e. data collected for any one tree may be different if someone were to collect the same data today. Therefore the data set should not be considered a static one, and requires periodic updating to remain useful for practical street tree management (also see **4 Recommendations**).

Despite the collection being 'tree specific' i.e. data was collected on each and every tree across the LGA, the data set should not necessarily be used for tree management on a case by case basis – some confirmation of data accuracy would still be required. While every effort was made to make the data as accurate as possible, it is probable that the data set contains errors. Spatial inaccuracies (of up to 10 m) are a certainty, and other data errors (for all other attributes) are possible. The former were due to inaccuracies associated with using handheld GPS to mark new entries (i.e. those not identified in the desktop assessment). Other errors are due to operator error e.g. misidentifications. While an experienced ecologist and an arborist collected the field data, some trees could not be identified to species level. In particular many of the Eucalypts that were prone to high levels of hybridization making them problematic to identify. Where there were doubts on the identification of a specimen (either at species or genera level), a '?' was used in the data sheet. Some genera were also very common (e.g. *Prunus* and *Callistemon*) and it was decided that the growth form of these species (among the genus) were similar and thus it was not worthwhile to expend the time on species level identification. These species were identified as 'sp.'

A small percentage (<1%) of data are also 'missing' or show as 'blank' in the data set. This was due to limitations of the method using Google StreetView. These small amounts of data are not considered significant to masking trends (see **Section 3.1**), and could be updated if required. It is notable that trees collected by Google StreetView were generally those located on the busy streets, and so would most likely require an observer on foot to fill these gaps. Nonetheless, we were still able to capture most information in nearly all cases.

3 Results and discussion

The following sections describe some of the trends across Hurstville LGA and within individual suburbs. It should be noted that this only answers a subset of questions (as set out in **Section 2.7**) and that there are many other relationships and statistics that can be mined from the dataset. For example, how many *Lophostemon confertus* are found within the suburb of Beverly Hills, how many of these have caused 'severe' damage to the footpath, and where are these individuals located? The number of queries that could be applied are many, and specific questions can and should be tailored to meet the specific needs of HCC.

It should also be noted that the trends described for individual suburbs (see **Section 3.2**) were derived from the data set as at 9 January 2015 (representing around 97% of complete data), while those reported across the whole Hurstville LGA (see **Section 3.1**) were from the complete dataset. The trends reported on the subset of data are not expected to change significantly following the addition of the remaining 3% of street tree data.

3.1 Trends across whole of Hurstville LGA

A total of 17,033 trees were identified in the Desktop GIS analysis. However, this number did not indicate the actual number of street trees in the LGA due to errors in the image interpretation. Some errors included where identified trees were actually shrubs (verification could only be done during field data collection), where trees were on private property or trees that were in bushland reserves or park land areas. After the field data phase was completed, the number of street trees was reduced to a total of 14,819 records. Of the positive identifications (i.e. excluding unidentifiable deciduous trees or those where the field observers could not identify with confidence), a total of 104 different genera were identified.

Figure 16 shows the species making up the greatest proportions of the total across the whole of the Hurstville LGA. Almost half (48%) the total number of trees (14,819) was made up of just two species (*Lophostemon confertus* and *Callistemon* sp.). The next most common species was *Eucalyptus microcorys,* making up around 7% of the total number. The category 'Others' was a mix of a wide range of genera and species, and made up of around 26% of the total number. These statistics were similar within each suburb (see **3.2**).

Where there was kerb and gutter present (Total = 14,391), there was no damage recorded in 83% of cases. Minor damage was recorded in 11% of cases, moderate damage in 4%, and less than 1% were considered to be in the severe category. Where the surrounding material was concrete or other hard-paved surface (Total = 6,766), there was no damage in 84% of cases. Minor, moderate and severe damage was recorded in 11, 3 and <1% of cases, respectively.

For tree health, the overwhelming majority (96%) were considered to be in good health. The remainder were in moderate (2%) or poor (1%) condition, while a few specimens (<1%) were considered dead.

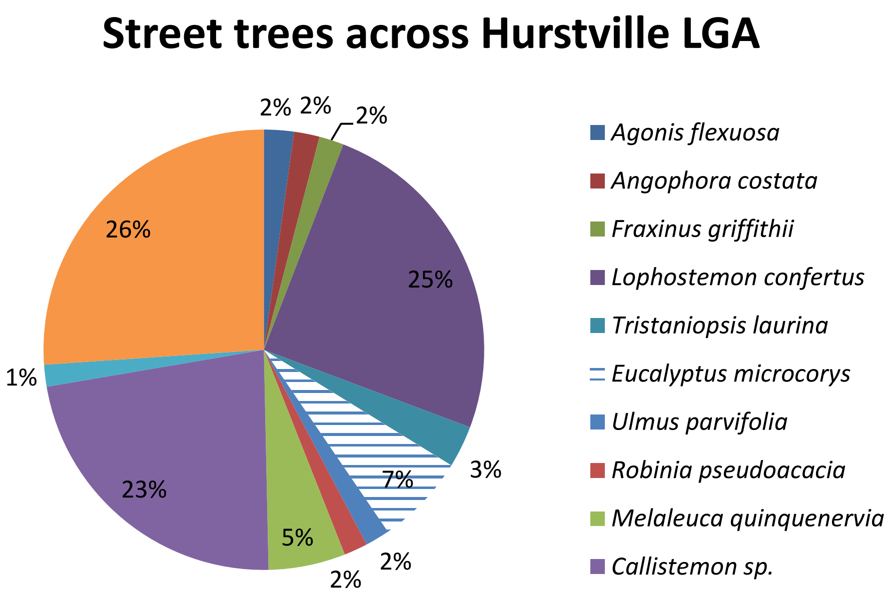


Figure 16: Proportion of species across the whole Hurstville LGA. The category 'Others' was made up species where there were only a few occurrences (generally less than 1% of the total each).

3.2 Trends across individual suburbs

The following sections (**3.2.1 - 3.2.12**) describe some of the trends within each suburb. As in **Section 3.1**, this section illustrates only some of the information that can be extracted.

3.2.1 Beverly Hills

Figure 17 shows the species making up the greatest proportions across the suburb of Beverly Hills. The category 'Others' was made up of species where there were only a few occurrences (generally less than 10 individuals or 1% of the total) and comprised a mix of species such as *Alnus jorullensis, Corymbia citriodora, Corymbia ficifolia* and *Gleditsia triacanthos*.

For the majority of street trees where there was kerb and gutter present (Total = 1694), there was no damage recorded in 89% of cases. Minor damage was recorded in 9% of cases, moderate damage in 2%, and <1% were considered to be in the severe category. Where the surrounding material was concrete or other hard-paved surface (Total = 645), there was no damage in 86% of cases. Minor, moderate and severe was recorded in 10, 3 and 0.5% of cases, respectively.

Approximately 96% of the trees were considered to be in good health, 2% in moderate health, and 1% in poor health.

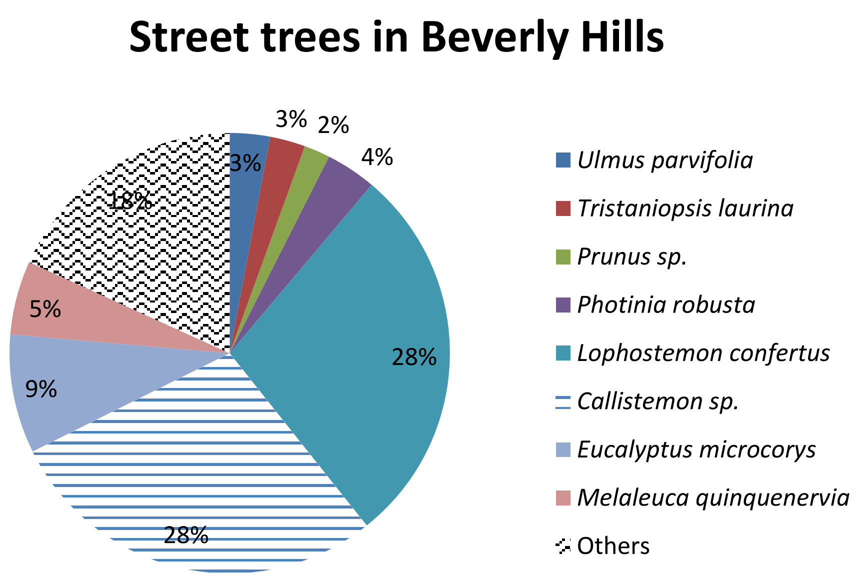


Figure 17: Proportion of species in the suburb of Beverly Hills

3.2.2 Carlton

Figure 18 shows the species making up the greatest proportions across the suburb of Carlton. The category 'Others' was made up of species where there were only a few occurrences (generally less than 10 individuals or 1% of the total) and comprised a mix of species such as *Macadamia* sp., *Olea* sp., *Ficus benjamina*, and *Syzigium* sp.

For the majority of street trees where there was kerb and gutter present (Total = 132), there was no damage recorded (92%). Minor damage was recorded in 8% of cases and Moderate damage in 4%. There were no instances of severe kerb and gutter damage. Where the surrounding material was concrete or other hard-paved surface (Total = 145), there was no damage in 70% of cases. Minor, Moderate and Severe was recorded in 19, 10 and 2% of cases, respectively.

Of the 162 trees, only one tree was considered to be in poor health. The remaining were in good health.

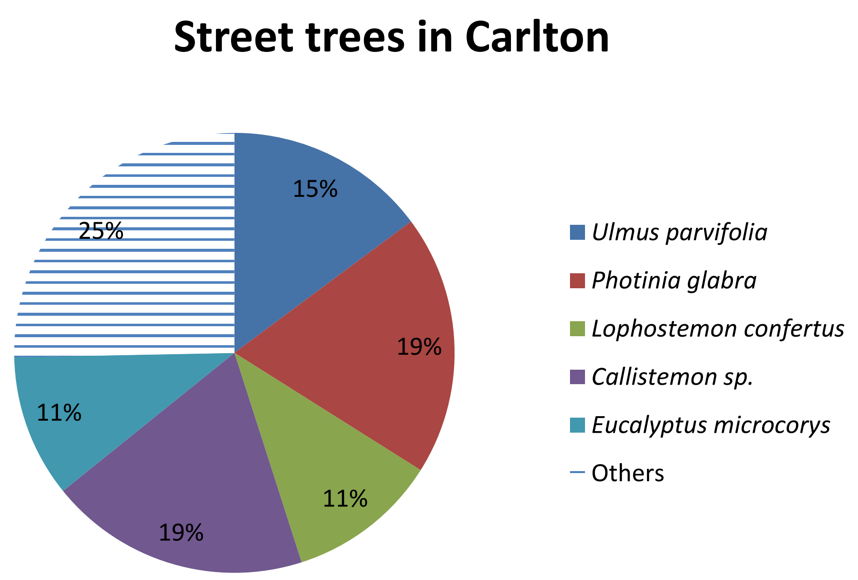


Figure 18: Proportion of species in the suburb of Carlton

3.2.3 Kingsgrove

Figure 19 shows the species making up the greatest proportions across the suburb of Kingsgrove. The category 'Others' was made up of species where there were only a few occurrences (generally less than 10 individuals or 1% of the total) and comprised a mix of species such as *Prunus* sp., *Photinia robusta, Corymbia citriodora,* and *Robinia pseudoacacia*.

For the majority of street trees where there was kerb and gutter present (Total = 921), there was no damage recorded in 77% of cases. Minor damage was recorded in 16% of cases and moderate damage in 6%. There were six instances of severe kerb and gutter damage (<1% of the total). Where the surrounding material was concrete or other hard-paved surface (Total = 316), there was no damage in 90% of cases. Minor damage was recorded in 10% of cases, while less than 1% was in moderate condition. There were no instances of severe damage.

Of the 953 trees, only 12 trees (1%) were considered to be in moderate health, and just five trees were in poor health (<1%).

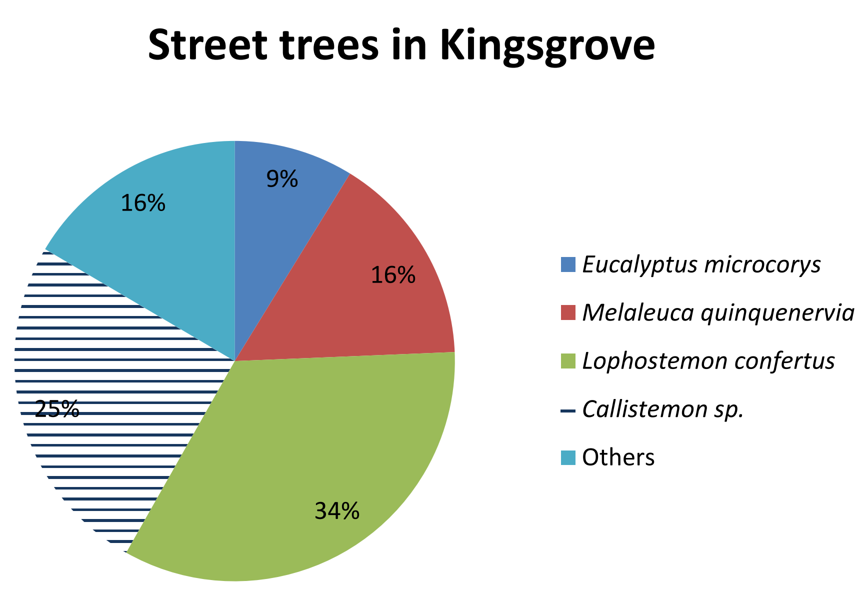


Figure 19: Proportion of species in the suburb of Kingsgrove

3.2.4 Narwee

Figure 20 shows the species making up the greatest proportions across the suburb of Narwee. The category 'Others' was made up of species where there were only a few occurrences (generally less than 10 individuals or 1% of the total) and comprised a mix of species such as *Jacaranda mimosifolia, Robinia pseudoacacia* and *Eucalyptus nicholii.*

For the majority of street trees where there was kerb and gutter present (Total = 291), there was no damage recorded in 94% of cases. Minor damage was recorded in 4% of cases and moderate damage in 2%. There were no instances of severe kerb and gutter damage. Where the surrounding material was concrete or other hard-paved surface (Total = 168), there was no damage in 91% of cases. 'Minor' damage was recorded in 6% of cases, while only 2% were in moderate condition. There were no instances of severe damage.

Of the 297 trees, only two trees were considered to be in moderate health, and just one tree was in poor health.

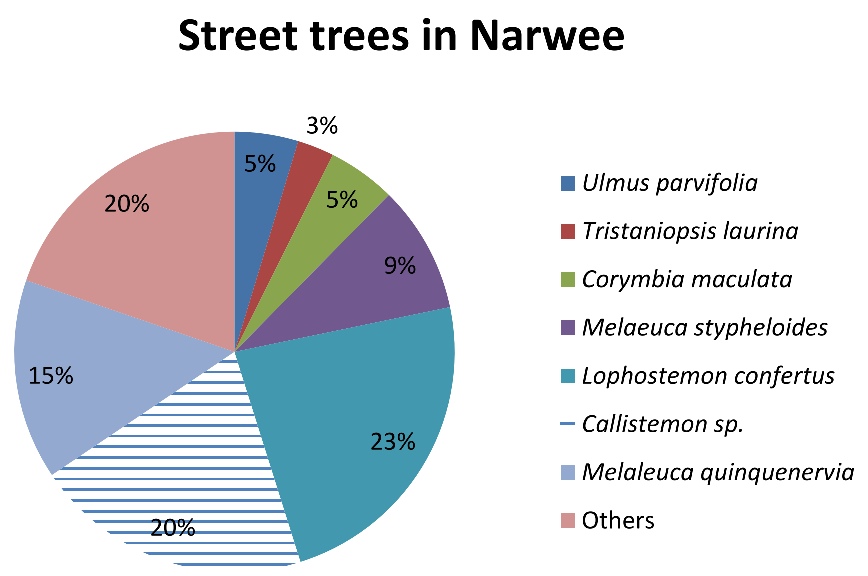


Figure 20: Proportion of species in the suburb of Narwee

3.2.5 Peakhurst Heights

Figure 21 shows the species making up the greatest proportions across the suburb of Peakhurst Heights. The category 'Others' was made up of species where there were only a few occurrences (generally less than 10 individuals or 1% of the total) and comprised a mix of species such as *Syagarus romanzoffianum, Banksia serrata, Prunus* sp. and *Olea* sp.

For the majority of street trees where there was kerb and gutter present (Total = 510), there was no damage recorded in 74% of cases. Minor damage was recorded in 19% of cases and moderate damage in 6%. There were four instances of severe kerb and gutter damage. Where the surrounding material was concrete or other hard-paved surface (Total = 106), there was no damage in 69% of cases. 'Minor' damage was recorded in 22% of cases, while 10% were in moderate condition. There was no instance of severe damage.

Of the 512 trees, only seven trees were considered to be in moderate health, and three were in poor health.

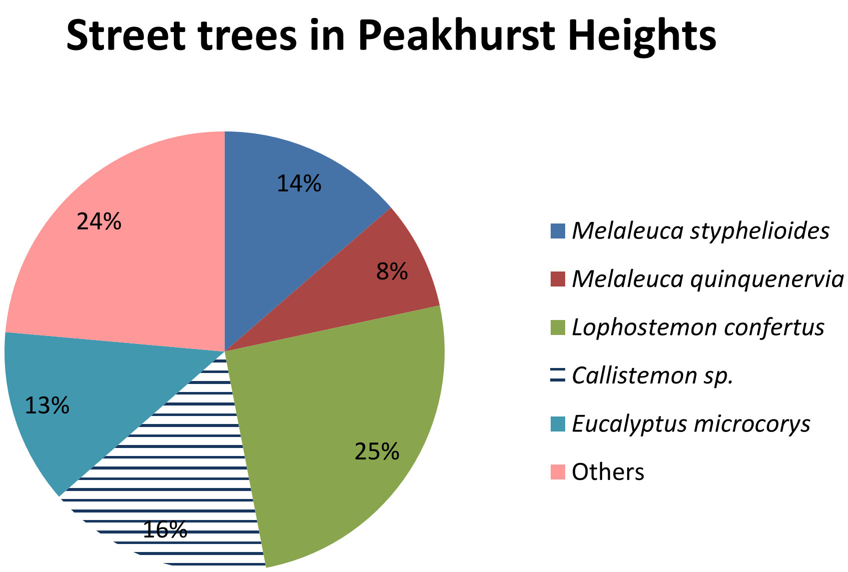


Figure 21: Proportion of species in the suburb of Peakhurst Heights

3.2.6 Peakhurst

Figure 22 shows the species making up the greatest proportions across the suburb of Peakhurst. The category 'Others' was made up of species where there were only a few occurrences (generally less than 10 individuals or 1% of the total) and comprised a mix of species such as *Syagarus romanzoffianum, Ulmus parvifolia, Triadica sebifera* and *Robinia pseudoacacia*.

For the majority of street trees where there was kerb and gutter present (Total = 1523), there was no damage recorded in 83% of cases. Minor damage was recorded in 12% of cases and moderate damage in 4%. There were 12 instances of severe kerb and gutter damage. Where the surrounding material was concrete or other hard-paved surface (Total = 521), there was no damage in 81% of cases. Minor damage was recorded in 16% of cases, while 3% were in moderate condition. There were only five instances of severe damage.

Of the 1536 trees, 42 (3%) were considered to be in moderate health, and 22 (1%) were in poor health. Four trees were found to be dead.

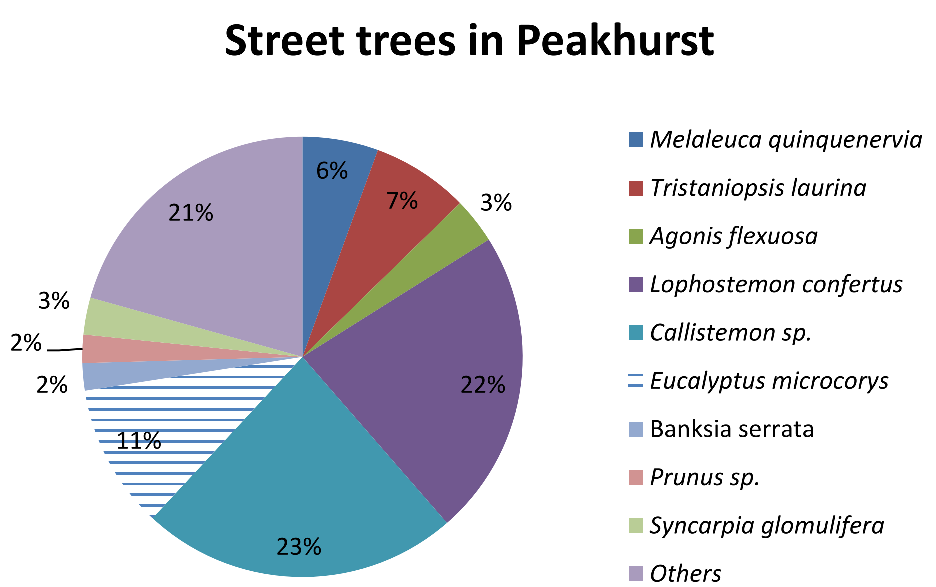


Figure 22: Proportion of species in the suburb of Peakhurst

3.2.7 Oatley

Figure 23 shows the species making up the greatest proportions across the suburb of Oatley. The category 'Others' was made up of species where there were only a few occurrences (generally less than 10 individuals or 1% of the total) and comprised a mix of species such as *Acacia buxifolia, Acmena smithii, Banksia integrifolia* and *Brachychiton acerifolius.*

For the majority of street trees where there was kerb and gutter present (Total = 1760), there was no damage recorded in 85% of cases. Minor damage was recorded in 10% of cases and moderate damage in 4%. There were 27 instances (2%) of severe kerb and gutter damage. Where the surrounding material was concrete or other hard-paved surface (Total = 493), there was no damage in 91% of cases. Minor damage was recorded in 7% of cases, while 2% were in moderate condition. There were no instances of severe damage.

Of the 1791 trees, 97% were in good health, 2% were considered to be in moderate health, and 17 individuals (or <1%) were in poor health.

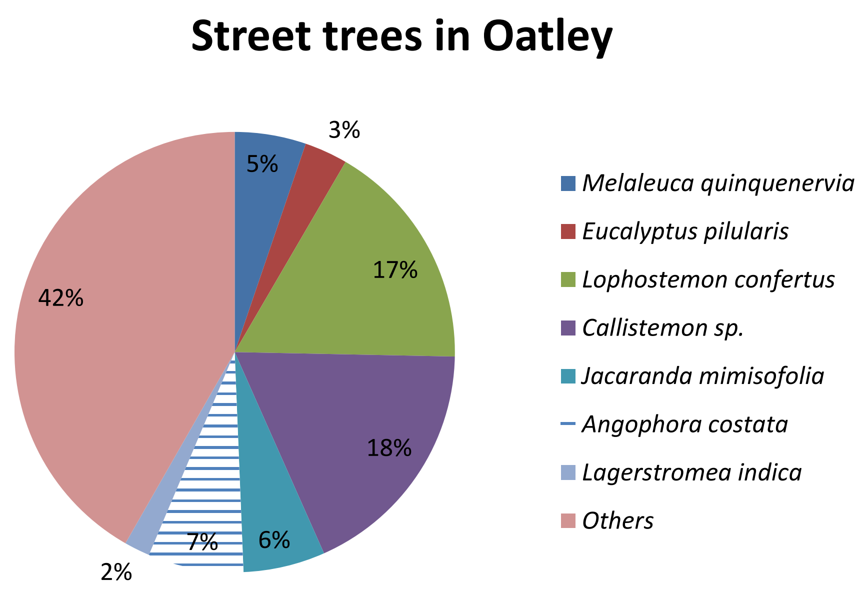


Figure 23: Proportion of species in the suburb of Oatley

3.2.8 Lugarno

Figure 24 shows the species making up the greatest proportions across the suburb of Lugarno. The category 'Others' was made up of species where there were only a few occurrences (generally less than 10 individuals or 1% of the total) and comprised a mix of species such as *Tristaniopsis laurina, Banksia serrata, Eucalyptus microcorys* and *Olea* sp.

For the majority of street trees where there was kerb and gutter present (Total = 671), there was no damage recorded in 87% of cases. Minor damage was recorded in 10% of cases and moderate damage in 3%. There were only two instances (<1%) of severe kerb and gutter damage. Where the surrounding material was concrete or other hard-paved surface (Total = 68), there was no damage in 85% of cases. Minor damage was recorded in 13% of cases, while there was only one case in moderate condition. There were no instances of severe damage.

Of the 698 trees, 96% were in good health, 3% were considered to be in moderate health, and six individuals (<1%) were in poor health.

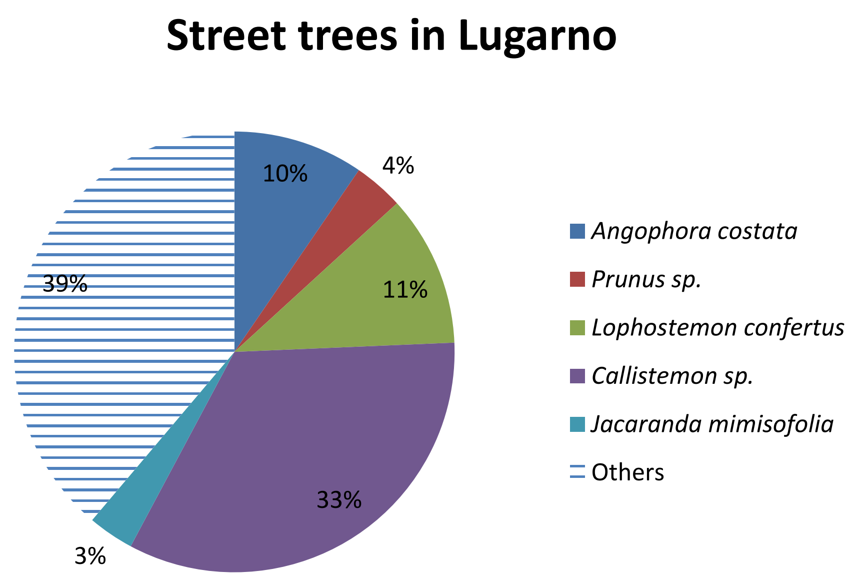


Figure 24: Proportion of species in the suburb of Lugarno

3.2.9 Penshurst

Figure 25 shows the species making up the greatest proportions across the suburb of Penshurst. The category 'Others' was made up of species where there were only a few occurrences (generally less than 10 individuals or 1% of the total) and comprised a mix of species such as *Gordonia axillaris, Harpephyllum caffrum,* and *Pheonix roebelenii.*

For the majority of street trees where there was kerb and gutter present (Total = 992), there was no damage recorded in 88% of cases. Minor damage was recorded in 8% of cases and moderate damage in 3%. There were only two instances (<1%) of severe kerb and gutter damage. Where the surrounding material was concrete or other hard-paved surface (Total = 848), there was no damage in 89% of cases. Minor damage was recorded in 10% of cases, moderate damage in 1%, while there was only one case with severe damage.

Of the 1005 trees, 96% were in good health, 3% were considered to be in moderate health, and 16 individuals (<2%) were in poor health.

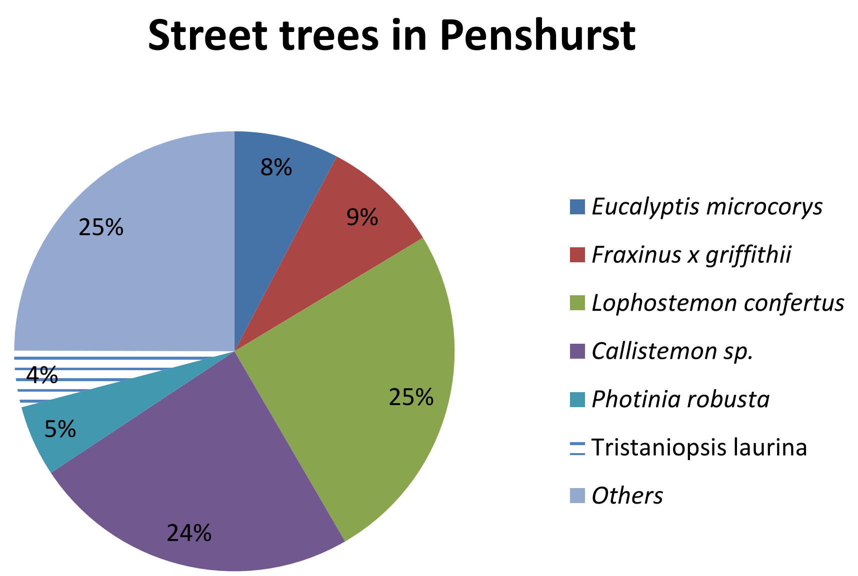


Figure 25 Proportion of species in the suburb of Penshurst

3.2.10 Mortdale

Figure 26 shows the species making up the greatest proportions across the suburb of Mortdale. The category 'Others' was made up of species where there were only a few occurrences (generally less than 10 individuals or 1% of the total) and comprised a mix of species such as *Pistacia chinensis, Jacaranda mimosifolia,* and *Schinus molle.*

For the majority of street trees where there was kerb and gutter present (Total = 1325), there was no damage recorded in 80% of cases. Minor damage was recorded in 14% of cases and moderate damage in 5%. There were 14 instances (1%) of severe kerb and gutter damage. Where the surrounding material was concrete or other hard-paved surface (Total = 818), there was no damage in 86% of cases. Minor damage was recorded in 11% of cases, moderate damage in 2%, while there were no cases with severe damage.

Of the 1351 trees, 96% were in good health, 3% were considered to be in moderate health, and 13 individuals (<1%) were in poor health.

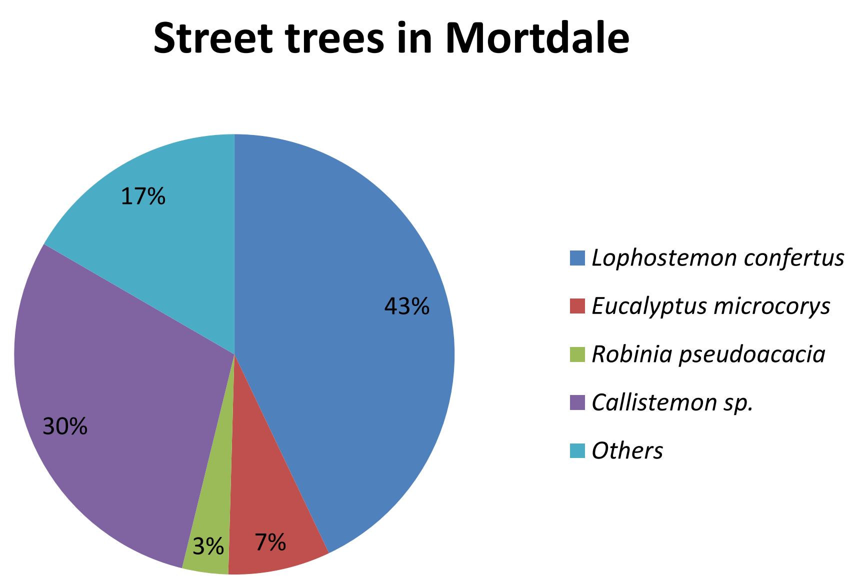


Figure 26: Proportion of species in the suburb of Mortdale

3.2.11 Riverwood

Figure 27 shows the species making up the greatest proportions across the suburb of Riverwood. The category 'Others' was made up of species where there were only a few occurrences (generally less than 10 individuals or 1% of the total) and comprised a mix of species such as *Syncarpia glomulifera, Jacaranda mimosifolia,* and *Corymbia citriodora.*

For the majority of street trees where there was kerb and gutter present (Total = 827), there was no damage recorded in 83% of cases. Minor damage was recorded in 11% of cases and moderate damage in 5%. There were six instances (<1%) of severe kerb and gutter damage. Where the surrounding material was concrete or other hard-paved surface (Total = 417), there was no damage in 86% of cases. Minor damage was recorded in 10% of cases, moderate damage in 3%, while there were only three cases with severe damage.

Of the 957 trees, 96% were in good health, 1% were considered to be in moderate health, and 3% were in poor health.

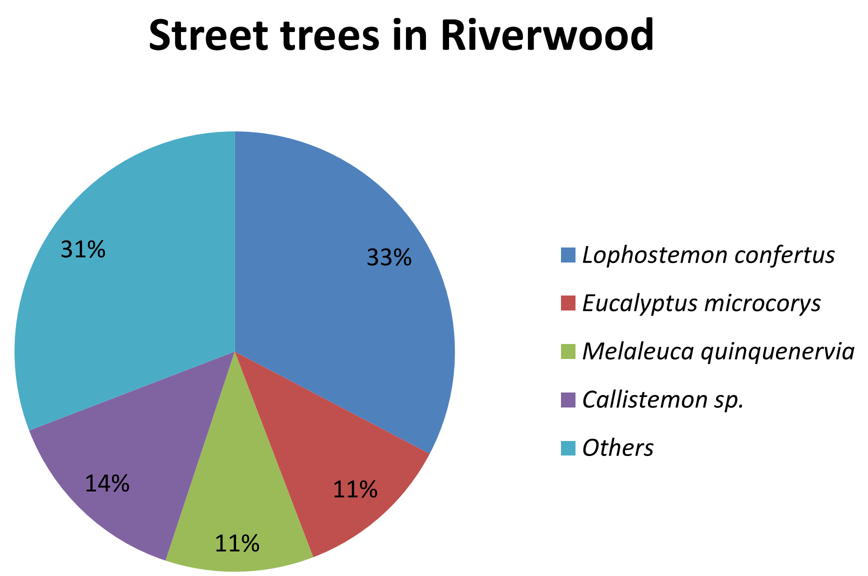


Figure 27: Proportion of species in the suburb of Riverwood

3.2.12 Hurstville

Figure 28 shows the species making up the greatest proportions across the suburb of Hurstville. The category 'Others' was made up of species where there were only a few occurrences (generally less than 10 individuals or 1% of the total) and comprised a mix of species such as *Eucalyptus scoparia, Lagunaria patersonia,* and *Platanus x hybrida.*

For the majority of street trees where there was kerb and gutter present (Total = 1942), there was no damage recorded in 81% of cases. Minor damage was recorded in 14% of cases and moderate damage in 4%. There were 18 instances (<1%) of severe kerb and gutter damage. Where the surrounding material was concrete or other hard-paved surface (Total = 1530), there was no damage in 81% of cases. Minor damage was recorded in 14% of cases, moderate damage in 4%, while there were 12 cases with severe damage.

Of the 2042 trees, 97% were in good health, 2% were considered to be in moderate health, and <1% were in poor health.

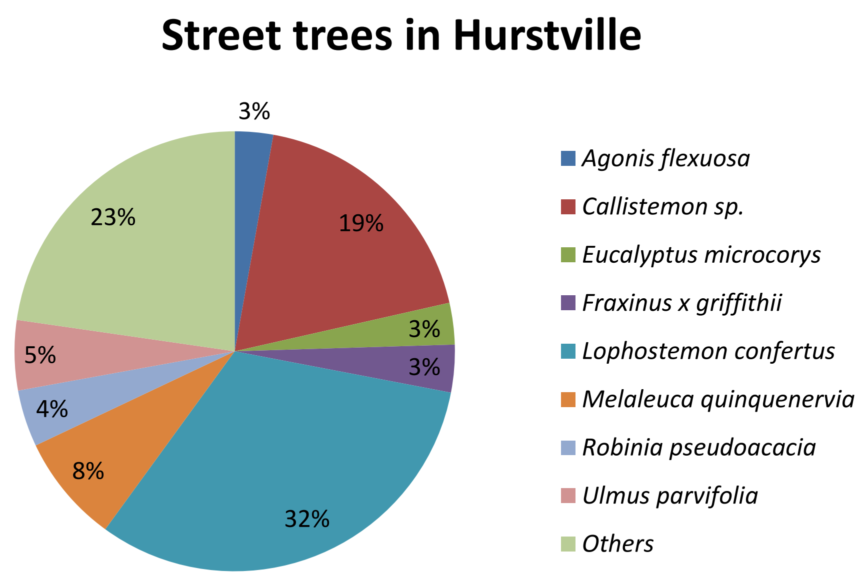


Figure 28: Proportion of species in the suburb of Hurstville

4 Recommendations

4.1 Maintain and use the data set

HCC now has a powerful set of data at their disposal. Despite some of the challenges in obtaining and maintaining these large data sets, it is vital they are maintained. HCC could consider an inspection program. This could be achieved by using subsets of the data in mobile electronic devices. Data would then be easily uploaded and integrated with the corporate data sets.

Using these methods eliminates the unnecessary steps of manual data transfer. Data sheets can be established whereby there are mandatory fields and limited data selection. This would minimise data errors and incomplete data sets. We recommend this commence with the trees that we were only able to capture through Google Street View.

4.2 Determine a direction for managing the street trees

As with the councils whose plans were reviewed, there are many opportunities to utilize and mine the data captured. We recommend that HCC holds a workshop to discuss the objectives required to manage the street tree assets. For example, the following questions may be useful to elucidate a direction for canopy management in the LGA:

- Does HCC wish to ensure no net loss of street tree canopy?
- What practices are in place to determine what species should be used to replace lost canopy?
- How would a replacement canopy species be treated in a hard paved area?
- Does HCC wish to integrate private canopy management with street tree and parkland or reserve canopy management?
- Is there an opportunity to establish a greenweb corridor in areas where the urban canopy is limited?
- Would a strategy outline in detail all of the procedures and guidelines, would it establish the direction for precincts?
- How would street tree management integrate with bush land management?

4.3 Ensure integration and management of risk

Early discussions with HCC staff indicated that there were challenges in integrating and acting upon intelligence collected regarding street tree management. For example, it was suggested there was a six-month backlog in addressing maintenance issues for street trees that were known to require management. The data collected during this study indicates there are some trees requiring immediate maintenance. It would be imperative for HCC to ensure that the risks identified are appropriately managed.

HCC have an online web-based form to apply for inspection of a tree on council controlled land. The intelligence gathered by the community is currently not integrated into the spatial systems or corporate data sets within HCC. It is understood that the web-based applications are printed onto a hard copy for action. With the data that this study has collected, there is an opportunity for HCC to better manage this asset and its risks by integrating a web based application form to the street tree asset register or spatial data sets.

4.4 Future planting

Street trees provide a long term legacy for the community with a range of environmental, social and economic benefits (Kurn et al 1994). Burden (2006) found that for a planting cost of between $250 and $600 (including the first three years of maintenance), a single tree returns over $90,000 of direct benefits over the lifetime of the tree. But experienced land developers and town planners have shown that simply planting street trees without due consideration is not sufficient to achieve high quality streetscapes (Mather and Morton 2008).

Council will need to apply the following principles (after Mather and Morton 2008) when planning and implementing future plantings to replace or augment existing street trees:

- maximise planting of trees in all streets and retain existing suitable trees wherever possible
- select species that are based on the native vegetation communities that occur in the Hurstville LGA (refer to **Table 3** which has been developed with reference to the Hurstville Biodiversity Study (ELA 2014))
- select species to provide scale and visual cohesion to the street
- select species to satisfy design intent and the physical conditions of the site (both natural and man-made)
- optimise soil and water conditions for trees including sufficient soil volume, quality and moisture
- minimise infrastructure and functional conflicts
- optimize the quality and local provenance of plant stock.

Other selection considerations and questions that need to be addressed by Council when planning future plantings are summarised below.

1. *What is the desired character of the suburb, precinct, or street?*

Character can be divided into three types:

- **Historic**, where existing species may reflect previous land use or a previous landscape design. Where there is an existing streetscape and species used, any infill planting should reinforce the existing character. In the majority of suburbs in the Hurstville LGA (i.e. all with the exception of Lugarno and Oatley), infilling with *Lophostemon confertus, Eucalyptus microcorys* and *Callistemon* spp. will maintain and reinforce the existing character.
- **Cultural**, where some species have special associations with a particular cultural group. The community can also exhibit strong attitudes in regard to their environment, including species of trees in their street. During the survey work for this report, the data collectors were often approached by residents with their own views on what should (and should not) happen with the trees in their street. Future involvement and education of the community would be imperative to ensure success of new street tree plantings.
- **Natural**, where street trees extend or reinforce the natural character of the area. The suburbs of Lugarno and Oatley are examples of where species selection should reinforce the natural character of the area by using species such as *Angophora costata* and *Tristaniopsis laurina*.

2. *What 'look' is desired for the suburb, precinct, or street?*

The 'look' of a street will depend on the existing and proposed planting configuration. This may take the form of:

- formal avenues, single species symmetrically spaced

- informal avenues, single species asymmetrically spaced
- patterned planting, multiple species in a pattern avenue or patterned group planting
- focal/landmark planting, trees used to highlight presence of an entry point or community point.

Once configuration has been determined, the following characteristics of species need to be considered:

- Tree form e.g. upright and vertical or broad domed canopy. Tree form is important if the 'classic' avenue of interlocking canopies is desired (e.g. *Ficus microcarpa* var. *hillii*). Conversely, trees with strong vertical forms (e.g. *Elaeocarpus reticulatus*) may suit more modern building architecture or where overhead infrastructure needs to be considered. Factors of individual streets, such as width of the footpath area, will necessarily dictate forms that can be used.
- Leaf colour or other visually appealing feature such as floral displays. Seasonal features such as flowers, leaf colour variation, attractive bark can all create an important aesthetic dimension.

3. *What is the climate of the area?*

While Sydney is considered to have a warm temperate climate, there is considerable variation across the region as a whole. There can also be significant variation in climate at small scales due to local topographic features (Ashcroft and Gollan 2012). For example, a local depression can experience frosts due to cold air pooling, while the surrounding landscape remains frost free. Since different species have different microclimatic preferences and tolerances depending on their natural habitat, consideration of the microclimate is important to consider when selecting species. In the Hurstville LGA, it is expected that areas with relatively low relief (e.g. Kingsgrove) would support species that are tolerant of exposure to full sunlight, while those that are more topographically complex (e.g. Peakhurst, Oatley and Como), will suit species that perform better in more sheltered positions.

4. *What soils are in the area and what is the drainage like?*

Just as climate can be variable over small distances, soils and drainage can also change quickly. Disturbed landscapes (as is the Hurstville LGA) can add to this complexity. Soil conditions within urban environments are far from natural where profiles are often inverted, paved over, compacted and obstructed by below-ground infrastructure. The selection of species must take these factors into account. While some species can tolerate a range of soil types, depths and water logging, others will quickly succumb and die, and if not, be susceptible to a range of pest and diseases.

5. *What services and public infrastructure are present?*

The size and position of underground utility services may limit effective root growth and the presence of overhead infrastructure (such as wiring) means that ongoing maintenance (e.g. pruning) will be needed to ensure required clearances. Careful consideration is needed as heavy pruning of certain species can destroy the aesthetic appeal. Pruning also adds to the ongoing cost of maintenance. Moreover, certain species have large and vigorous root systems, which may result in significant damage to infrastructure such as kerbs, footpaths and road pavement.

6. *Should natives or exotics be planted?*

Native species of local provenance are preferred because they are best suited to the soils and climate of the area. Local native species can also provide important 'stepping stones' and linkages to bushland remnants. 'Escapees' to surrounding bushland reserves are also less of a concern than exotics or species not endemic to the areas.

4.5 Conclusions

The capture and acquisition of street tree data across the whole Hurstville LGA is a significant step for HCCs street tree management. There is a wealth of opportunities now available for ensuring that these important assets are managed with the best available data. However, producing a definitive list of trees for each suburb, precinct or individual street remains a considerable challenge due not only to the enormous variation across the LGA, but also within individual streets. The recommended species list (**Table 3**), and the guiding principles and questions needed to be considered (see **Section 4.4**) will assist Council and the community in making more informed choices.

Table 3: Recommended street trees for the Hurstville LGA

Scientific name	Common Name	Community	Soil Conditions				Drainage Requirement		
			Shale	Sandstone	Transitional	Alluvium	Good	Average	Poor
Small Trees (Height 6-8m x Spread 4-5m)									
Elaeocarpus reticulatus	Blueberry Ash	CESDF	✓	✓	✓	✓	✓	✓	✗
Banksia serrata	Old-man Banksia	CESDF SHESW	✗	✓	✗	✓	✓	✓	✗
Backhousia myrtifolia	Grey Myrtle	CESMF	✓	✓	✓	✓	✓	✓	✗
Callistemon citrinus	Bottlebrush	RPSF	✓	✓	✓	✓	✓	✓	✓
Melaleuca decora	White Feather Honey Myrtle	CRF	✓	✗	✓	✓	✓	✓	✓
Melaleuca linarifolia	Narrow-leaved Paperbark	RPSF	✓	✓	✓	✓	✓	✓	✓
Medium Trees (Height 10-12m x Spread 8-9m)									
Tristaniopsis laurina	Water Gum	SFSF	✓	✓	✓	✓	✓	✓	✓
Acmena smithii	Lillypilly	CELR	✓	✗	✓	✓	✓	✓	✗
Corymbia gummifera	Red Bloodwood	CESDF SHESW	✗	✓	✓	✗	✓	✗	✗
Melaleuca styphelioides	Prickly-leaved Paperbark	RPSF	✓	✓	✓	✓	✓	✓	✓
Large Trees (Height 16-20m x Spread 16m)									
Eucalyptus tereticornis	Forest Red Gum	SFSF	✓	✓	✓	✓	✓	✗	✗
Eucalyptus fibrosa	Broad-leaved Ironbark	STIF	✓	✗	✓	✓	✓	✗	✗
Eucalyptus crebra	Narrow-leaved Ironbark	STIF	✓	✗	✓	✓	✓	✓	✗
Angophora floribunda	Rough-barked Apple	RPSF	✓	✓	✓	✓	✓	✓	✓
Eucalyptus punctata	Grey Gum	SHAGF	✗	✓	✓	✓	✓	✓	✗

Scientific name	Common Name	Community	Soil Conditions				Drainage Requirement		
			Shale	Sandstone	Transitional	Alluvium	Good	Average	Poor
Syncarpia glomulifera	Turpentine	STIF CSSF	✓	✓	✓	✓	✓	✓	✗
Eucalyptus piperita	Sydney Peppermint	CESDF	✗	✓	✓	✗	✓	✓	✗
Angophora costata	Smooth-barked Apple	CESDF CSSF	✗	✓	✓	✗	✓	✓	✗

Community names: CESDF – Coastal Enriched Sheltered Dry Forest, CESMF – Coastal Enriched Sheltered Moist Forest, CSSF – Coastal Shale Sandstone Forest, CELR – Coastal Escarpment Littoral Rainforest, CRF – Cumberland Riverflat Forest, RPSF – Riverflat Paperbark Swamp Forest, SHAGF – Sydney Hinterland Apple-blackbutt Gully Forest, SHESW – Sydney Hinterland Exposed Sandstone Woodland, SFSF – Sydney Foreshores Shale Forest, STIF – Sydney Turpentine Ironbark Forest.

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HEAD OFFICE
Suite 4, Level 1
2-4 Merton Street
Sutherland NSW 2232
T 02 8536 8600
F 02 9542 5622

SYDNEY
Level 6
299 Sussex Street
Sydney NSW 2000
T 02 8536 8650
F 02 9264 0717

ST GEORGES BASIN
8/128 Island Point Road
St Georges Basin NSW 2540
T 02 4443 5555
F 02 4443 6655

CANBERRA
Level 2
11 London Circuit
Canberra ACT 2601
T 02 6103 0145
F 02 6103 0148

NEWCASTLE
Suites 28 & 29, Level 7
19 Bolton Street
Newcastle NSW 2300
T 02 4910 0125
F 02 4910 0126

NAROOMA
5/20 Canty Street
Narooma NSW 2546
T 02 4476 1151
F 02 4476 1161

COFFS HARBOUR
35 Orlando Street
Coffs Harbour Jetty NSW 2450
T 02 6651 5484
F 02 6651 6890

ARMIDALE
92 Taylor Street
Armidale NSW 2350
T 02 8081 2681
F 02 6772 1279

MUDGEE
Unit 1, Level 1
79 Market Street
Mudgee NSW 2850
T 02 4302 1230
F 02 6372 9230

PERTH
Suite 1 & 2
49 Ord Street
West Perth WA 6005
T 08 9227 1070
F 08 9322 1358

WOLLONGONG
Suite 204, Level 2
62 Moore Street
Austinmer NSW 2515
T 02 4201 2200
F 02 4268 4361

GOSFORD
Suite 5, Baker One
1-5 Baker Street
Gosford NSW 2250
T 02 4302 1220
F 02 4322 2897

DARWIN
16/56 Marina Boulevard
Cullen Bay NT 0820
T 08 8989 5601
F 08 8941 1220

BRISBANE
Suite 1 Level 3
471 Adelaide Street
Brisbane QLD 4000
T 07 3503 7191
F 07 3854 0310

1300 646 131
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