ATTACHMENT B

ESTABLISHING A RESILIENT URBAN FOREST FOR DARWIN

Best Practice Guidelines

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Cyclone Marcus 2018

Executive Summary

Cyclone Marcus went over Darwin on 17th March 2018. For a category 2 cyclone with wind gusts up to 130 km/hour, the damage seemed disproportionately high. The visual impact of the number of very large trees uprooted and subsequent power interruptions and infrastructure damage will remain with many residents as the indelible memory of Cyclone Marcus. A review was required to understand why so many trees failed.

The review firstly established that regardless of the best efforts and following of best practice, the community must acquire an acceptance of, and an expectation that some tree failures and losses will occur during storm events. Tree risk management options are presented in the 'Whole of Life Tree Management' section. This is an area recommended for further community consultation and education.

This report presents an assessment of 219 tree species against several attributes that contribute to cyclone resilience. Appendix A is the preferred tree list for Darwin with 194 species. Whilst a heavy weighting has been placed on observed cyclone resilience, in selecting tree species for a location it is not solely about cyclone resilience. A tree species with low or medium cyclone resilience may have a particular attribute, such as form, colour, wildlife attractant etc. that is desirable in that landscape design for a location. Some low cyclone resilience species are small and unlikely to cause damage in the event of uprooting. Appendix A therefore includes a mix of species with high, medium and low cyclone resilience. The use of any of these species needs to be tempered by an understanding of their performance in storm events and the conditions of the planting site.

Appendix B contains 25 species not recommended for planting in Darwin. This includes many with a low cyclone resilience. In addition, there are species that are highly cyclone resilient but are not recommended for planting in particular locations for other reasons such as being allergenic/poisonous, are invasive, or have nuisance fruit.

Tree Selection

Darwin Urban Forest

To achieve the outcome of a stable tree that has a high resilience to cyclonic events requires attention to the entire life cycle of the tree. This starts with the selection of the most appropriate species through to the whole of life management of the mature tree. This report discusses the best practice options at each of the stages of plant selection, plant procurement and supply, tree installation, and whole of life tree management and provides many technical suggestions and recommendations to improve tree stability in storm events.

To facilitate future selection of tree species a matrix template of factors to be considered for any species has been developed as an aid to decision-making. These fields are presented in Appendix C and the matrix is available in the form of an Excel spreadsheet.

Some tree species appear to be more susceptible to failure in storms and others appear to have some inherent characteristics that make them more resistant, however, the majority of tree failures during storms across the Greater Darwin region can be attributed to lack of maintenance such as pruning, or root disturbance caused by cutting or damage. The report discusses tree protection and maintenance regimes. These are identified as the critical and predominant factors in improving tree stability with the clear message that a priority should be given to adopting mechanisms that avoids such damage to trees.

While the report has a focus on individual tree species there is also a discussion around the concept of developing an urban forest and the recognition of the numerous benefits that not only individual trees bring but also when trees form an urban forest. A range of trees of varying ages and attributes will collectively have a greater cyclone resilience. Such diversity is an important aspect of a resilient urban forest.

Recommendations

A summary of the key recommendations is presented grouped under the headings found within the report.

Plant Selection

1. *THAT* further evaluation should be done on the tree species in numerous individual planting sites in addition to the evaluation of many potentially suitable species that are not currently represented in the Darwin region.

2. *THAT* ongoing trials and research on potential new tree species for landscaping in Darwin could be supported by City of Darwin and undertaken collaboratively with various stakeholders in Darwin.

3. *THAT* most of the tree species in Appendices A and B are 'Unknown' for climate change resilience. This is an area in need of further research that could be promoted by City of Darwin.

4. *THAT* City of Darwin has the opportunity to liaise with the community and assess community attitudes about trees being replanted, what species, where they should be planted, and what their idea of a walkable liveable cool suburb is.

Tree Lists

5. *THAT* City of Darwin officers over time complete the desired attribute fields nominated in Appendix C to the tables shown in Appendix A and B.

Plant Procurement and Plant Supply

6. *THAT* City of Darwin prefer tree supply be given to Nursery Industry Accreditation Scheme Australia Accredited nurseries. The accreditation provides an audited best practice system for production nurseries that ensures high quality plant stock.

Pre-order and lead times

7. *THAT* City of Darwin continue with the contract for the supply of container grown trees.

Tree Installation

8. *THAT* City of Darwin follow the Australian Standard *AS 4419-2003 Soils for Landscaping and Garden Use* with the use of "Sandy Loam" in the tree pit.

Irrigation, water harvesting

9. *THAT* City of Darwin stipulate for all tree management that watering should deliver a suitable volume of water in such a way that it penetrates the soil profile to a depth of at least 450mm.

10. *THAT* City of Darwin stipulate in civil design projects that stormwater harvesting using storm water collection inlets should be installed wherever possible, and mandatory within the CBD.

Tree data base and data collection

11. *THAT* City of Darwin use a database to systematically inventory park and street tree assets. Goal is 100% of trees in the City of Darwin municipality be identified and plotted over a 3-year period.

12. *THAT* City of Darwin program reassessment of every tree every 3 years.

13. *THAT* City of Darwin provide appropriate Council officers and arborists with adequate resources for emergency operational data gathering to react promptly following an event.

14. *THAT* City of Darwin regularly review this report and the associated tree lists every 3 years or after a significant storm event.

Ongoing maintenance and associated funding – trees are a valuable community asset

15. *THAT* City of Darwin adopt the City of Melbourne tree valuation methodology.

16. *THAT* City of Darwin actively manage the loss of trees in the municipality to maintain and increase current canopy cover levels in public open space to a minimum of 50% by 2030.

17. *THAT* City of Darwin review the Tree Management Plan to ensure it reflects the findings of this report and any recommendations endorsed by council.

18. *THAT* City of Darwin reviews its resources to maintain the urban forest to a satisfactory level.

19. *THAT* City of Darwin updates its existing policy, procedures and processes for all tree related management to meet the organisational requirements for tree risk management, tree condition assessment, tree removal, tree retention, tree replacement and development consent.

20. *THAT* City of Darwin prepare a citywide, long-term Strategic Urban Forest Management Plan.

Pruning

21. *THAT* City of Darwin adopt *AS4373-2007 Pruning of Amenity Trees* as the standard for maintaining trees.

Monitoring/ risk management/ acceptable risk thresholds

22. *THAT* City of Darwin adopts an industry standard, peer reviewed, tree risk assessment system.

23. *THAT* City of Darwin conduct further community consultation and education to ensure the community understands the balance between an acceptable level of tree risk and the type of landscape that is envisaged for Darwin.

Tree protection

24. *THAT* City of Darwin adopt AS4970-2009 Protection of Trees on Development Sites as the standard.

25. *THAT* City of Darwin adopt mechanisms to enforce tree protection.

26. *THAT* City of Darwin review existing measures in other LGAs such as by-laws, Tree Protection Orders, Vegetation Protection overlays, tree removal/pruning permit systems, development consent requirements and the associated need for resourcing of such systems, including enforcement and surveillance.

Education

27. *THAT* City of Darwin develop and deliver tree management education programs to tree management staff, tree workers, parks crews, all contractors, (including irrigation), development assessment staff, customer service staff, high level decision makers and the wider community.

Jingili Water Gardens Urban Forest

Lake Alexander Urban Forest

Introduction

The development of an urban forest for Darwin that has improved cyclone resilience requires an explicit recognition of the numerous contributions that trees make to a city and the community. These benefits are discussed in the section on *'Why Plant Trees?'*. The Darwin community needs to recognise that there will always be risks associated with trees and storm events but a city without trees would be an unthinkable outcome. The community needs to understand the balance between an acceptable level of risk and type of landscape that is envisaged for Darwin. Tree risk management options are presented in the Whole of Life Tree Management section. This is an area recommended for further community consultation and education.

To achieve the outcome of a stable tree that has a high resilience to cyclonic events requires attention to the entire life cycle of the tree. This starts with the selection of the most appropriate species and includes the processes of procurement, propagation, tree installation and then the whole of life management of the mature tree. A tree can be compromised at any one or more of these stages resulting in an inherently less stable tree. This report discusses the best practice options at each of these stages. This in turn will also maximise the value of trees as essential urban infrastructure and a community asset.

Presented in this report is a list of 219 tree species that have been assessed primarily for their cyclone resilience (Appendices A and B).Cyclone resilience is not the only factor that should influence the selection of trees within Darwin. There is no one perfect tree for Darwin. A range of trees of varying ages and attributes are needed to create diverse plantings that, collectively, have a greater cyclone resilience. Such a diverse tree collection is an important aspect of a resilient urban forest. There are species that are highly cyclone resilient but are not recommended for planting in particular locations for other reasons such as being allergenic/poisonous, invasive, or having nuisance fruit. These species are included in Appendix B.


Yanyula Park

Conversely, a tree with low cyclone resilience may have an attribute such as form, colour or wildlife attractant that is desirable in a location. Where these trees are small, such as many Grevilleas and Acacias, and unlikely to cause damage in the event of uprooting, they have been included in Appendix A. The use of these species needs to be tempered by an understanding of their performance in storm events. Choosing the right trees for a site is also about factors such as proximity to infrastructure, space constraints, soil type and depth, watering regime and purpose of tree.

To facilitate future selection of tree species a matrix template of factors to be considered for a species has been developed as an aid to decision-making. These fields are presented in Appendix C and the matrix is available in the form of an excel spreadsheet. The fields relating to cyclone resilience, geographic origin, invasiveness and height x spread have been completed. It is recommended that this task should be completed for the remaining fields. Appendix C also presents a further list of attributes that should be considered in an expanded matrix tool.

Cyclone Marcus 2018

Trees and cyclone resilience

"Species have been reported to show differences in resistance to Tropical Cyclone force winds. But wind resistant species only buys you so much protection. I think the more important factors are:

1) soil and site conditions, and

2) tree defects in the crown and root system;

I think these outweigh the importance of species, perhaps by a lot. Lists of wind tolerant trees vary because factors 1 and 2 above over-ride species so often.

So let's dispel the myth that we can solve wind related tree failure by selecting the right species alone

…… There is much to this and simply recommending species does a great disservice to our community."1

1. *https:hort.ifas.ufl.edu/woody/wind.shtml*

Shallow Roots

Resilient Forest

While cyclones pose an enduring threat to Darwin, this does not mean yards and public spaces should be without large trees. All large trees in Darwin are sufficiently mature to have survived at least one cyclone, and many trees have endured through many severe cyclonic and storm events. The wind speed, direction, duration, and the level of soil saturation are all are involved with tree failure under high wind loads.

Many tree failures during storms can be attributed to lack of formative pruning and associated tree defects, such as bark inclusions on co-dominant stems, as well as wounds resulting in decay columns causing mechanical weakness. Soil saturation from heavy rain events leads to soil failure causing root plate destabilisation. Other factors include root disturbance, cutting or damage with associated fungal infections prior to a storm which contribute to root plate failure. By avoiding such damage to trees, cyclone resilience will clearly be improved.

Room for tree roots to anchor, through appropriate tree pit design and tree planting techniques, coupled with the selection of quality trees for planting will have a significant impact in reducing tree failure during storm events. Careless maintenance causes fungal infections of root systems which in turn lead to mechanical weaknesses. These issues can generally be rectified by appropriate design and thoughtful maintenance. Tree installations, with a focus on the most suitable tree for the location, combined with sensible and sustainable design and appropriate arboricultural maintenance will improve urban forest resilience against severe tropical storms and cyclones.

The community must acquire an acceptance of, and an expectation that some tree failures and losses will occur during storm events. It is impossible to have trees around people without any risk at all. In severe storm events, some trees will fall over, some will break apart, others will damage fences, cars, and buildings and other infrastructure. Many will also stand and continue to provide shade and environmental functions long after the storm has passed.

Physiological, sociological, economic and aesthetic benefits.

A resilient urban forest

The concept of an Urban Forest is utilised in the City of Darwin (CoD) CBD Master Plan (2015) and is a concept supported in this report. The following is a quote from the Darwin CBD Masterplan.

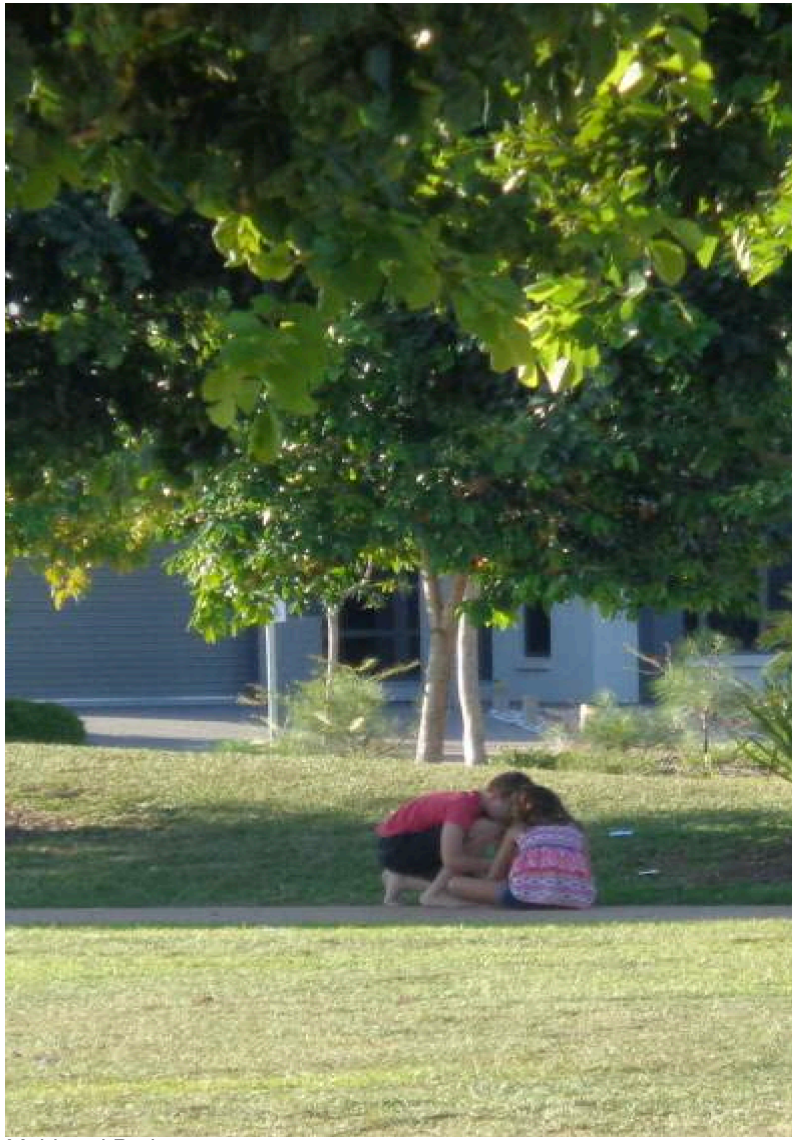
> *"The Urban Forest comprises the trees and vegetation throughout the Darwin City Centre, inclusive of all tree types and irrespective of whether they are on streets, in parks or on private land.*
>
> *The Urban Forest, measured as a canopy cover percentage of the total land area, is recognised as a primary component of the urban ecosystem (LGA NSW 2003). It is one component of the complex-built environment along with roads, car parks, buildings, footpaths and services. Urban forests in and around urban communities provide physiological, sociological, economic and aesthetic benefits.*
>
> *They are one of the most effective means of cooling a city and have been shown to greatly reduce urban heat island effects. Streetscapes and public realm open space will play a key role in the Urban Forest.*
>
> *It is important that adequate provision in terms of space (above ground and underground) is made for trees.*
>
> *In addition to the initial capital costs of installing trees, there should be realistic ongoing funding for tree maintenance and management to ensure the potential benefits are fully realised.*
>
> *The development of individual sites by the private sector has an impact on the potential benefits of the urban forest through tree planting, green roofs, increased reflection of heat."2*
>
> *2 City of Darwin CBD Masterplan 2015*

Change

Adoption of an Urban Forest concept brings with it a fundamental change to the approach in the way trees are viewed and managed. The following table summarises these changes to the approach to urban trees in Darwin:

Where we have been… Traditional Urban Tree Management	Where we need to be… Modern Urban Forestry Model
Trees as ornaments	Trees viewed as critical infrastructure
Focus on individual trees	Focus on overall canopy cover and forest
Trees treated with low priority	Trees have equal priority to other urban infrastructure such as roads and services
Trees have no monetary or economic value	Economic value of forest recognised and valued
Focus on smaller and ornamental species	Focus on larger longer-lived canopy trees
Individual tree maintenance	Overall forest management
Aesthetic based design only	Ecological and aesthetic based design
Legal boundaries determine tree management	Urban forest seen as continuous resource regardless of ownership boundaries

Table: Traditional versus modern urban forest approach (Source: North Sydney Council 2011)



Muirhead Park

WHY PLANT TREES?

> *"It is a sign of a great civilisation when old men and women plant trees that they may never sit under to enjoy the shade"*
> Greek Saying

It is true, that planting a tree is an investment in the future. It is also true that trees have much greater value than just providing a shady spot to sit and socialise. In our developing cities, trees provide multiple benefits and recent studies indicate that their value to society can be significant. Preliminary research for the Darwin CBD trees undertaken in 2016 valued the trees at $2.4M.

In cities around Australia and the world, trees are increasingly being recognised as important Green Infrastructure, and the development of Urban Forests within our cities is becoming mainstream policy.

In our tropical city, trees are a key aspect of reducing temperatures. Dense shady tree canopies can reduce surface temperatures by up to 25 degrees and assist in reducing the overall ambient temperature. Studies have shown that this cooling effect can reduce air-conditioning costs for adjoining properties by thousands of dollars per year.

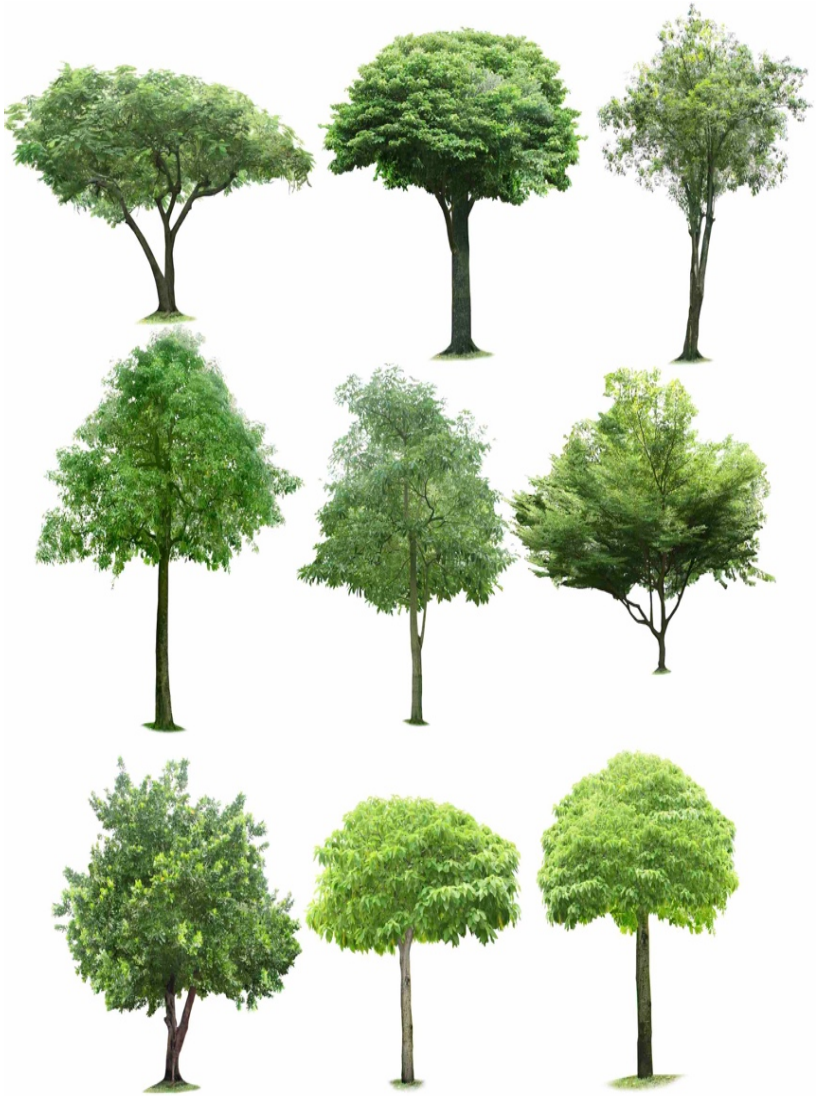
Trees are an important part of our culture, identity and character. Within Darwin, the Tree of Knowledge, the large Boab in the Post Office Carpark and numerous other Milkwoods, Banyans and Beauty Leafs are distinct and highly valued by the community. They have been meeting places providing shade and amenity for many years. They have also survived at least 4 cyclones - in 1917, 1937, 1974 (Tracy) and more recently 2018 (Marcus). Numerous surveys and public consultation undertaken by NTG and City of Darwin testify to the public's support for 'a lush, shady, tropical' city. There is widespread appreciation of tree lined shady streets and parks.

Darwin Botanical Gardens

Numerous studies within Australia and internationally demonstrate that well treed streets and suburbs are also those with higher property values. They are an investment with good returns for both private property owners and the community.

Trees provide valuable environmental benefits. Models developed and used in Australia demonstrate that the annual environmental contribution of a large, evergreen tree can be in the order of $10,000 and higher. This is in the areas of storing carbon (counteracting carbon emissions), removal of air pollutants and particles, water retention and cleansing. Trees can also contribute to infrastructure savings by reducing flooding levels and extending the life of road pavements.

Open space, parks and trees all make important contributions to the health and well-being of residents and visitors. Shady streets and parks promote physical and social activities. This translates directly to improved physical and mental health and has been shown to result in significant reductions in health costs.



Characteristics of trees

PLANT SELECTION

Plant selection is the first and most important step in the process of establishing a healthy, resilient tree. The golden rule should always be “The right tree for the right place”.

Consider the Strategic Aspects of an Urban Forest

- Life cycle (e.g. succession planting) considerations.
- Climate change considerations.
- Species diversity as part of a resilient urban forest. Many councils have a diversity plan along the lines of no more than 30% of one family, 20% of one genus and 10% of one species. This will help stagger growth rates of trees, avoid repeating past mistakes, (too many of one species of a similar age around the entire area) assist with allowing for climate change predictions and provide a more diverse selection of options.
- Maintenance and tree establishment commitment – resources and costs.

Consider the Physical Site Characteristics

Trees take time to develop and mature – they are living systems and their environment will greatly impact on how well they establish, mature and survive. Consider:

- Existing soils, natural drainage and water movements.
- Irrigation – permanent, temporary, establishment only or none.
- Shading and exposure arising from other trees, buildings and structures.
- Fast growth or long-term stability – these are often at odds.
- Available space – both above ground and below ground – refer to ‘Tree Installation’ section.
- Constraints such as underground and overhead services and the associated authority guidelines.

Raintree Park


Nature Playgrounds

Consider the Functional Requirements of Trees

- Shade to buildings, streets parks and open space.
- Creation of comfortable microclimates within outdoor spaces.
- Opportunities to educate (science studies, animal and plant interaction such as caterpillars, basis for art lessons, caring for land and Indigenous studies) and demonstrate sustainable land management practices.
- Indigenous local plantings provide habitat for native fauna and increase biodiversity values in the local area.
- Planting in the playground can inspire exploration, social interaction, learning and controlled risk taking for children.
- General; amenity and appearance.

From the above it can be seen that there are many aspects to be considered in plant selection. The Appendices to this report provide guidance on tree selection in respect of cyclone resilience, weed risk and other limiting factors, but this should only be the starting point in refining the final tree selection.

Appendices A and B are primarily a review of the list tree species that are known to be planted in and around Darwin. As such it is a limitation of the report. Further work should be done in relation to the evaluation of the myriad of individual planting sites along with the evaluation of many potentially suitable species that are not currently represented in the Darwin region. Included here would be also those species in the 'Inconclusive' category of cyclone resilience in Appendix A.

These species represent possible options to increase the diversity of species available for planting and may also represent species with favourable attributes under future climate scenarios. This is a field for ongoing trials, research and risk assessment that could be supported by City of Darwin and undertaken collaboratively with various stakeholders in Darwin.

Tree Canopy Adds to Walkable Neighbourhoods

The consideration of tree selection in future climate change scenarios is of increasing importance. Will tree species planted today cope with the temperature, rainfall and storm events predicted under future climatic conditions predicted for Darwin? Kendal *et al.* (2017) provide data on the risk of temperature rises due to climate change on trees in the Darwin CBD. Alarmingly, all of the 41 tree species assessed were flagged as at risk with temperature rises under a 'business as usual' scenario by 2070. Climate change resilience has been included in the tree selection matrix in Appendix C. However, it must be noted there is a paucity of data available for tropical trees. Most of the species in Appendices A and B are City of Darwin as 'Unknown' for climate change resilience. This is an area in need of further research that could be carried out in Darwin.

There is also the aspect of educating and responding to community aspirations for tree selection. The City of Darwin has the opportunity to liaise with the community and assess community attitudes about trees being replanted, what species, where they should be planted, and what their idea of a walkable liveable cool suburb is.

City of Darwin Nursery

Nursery Stock

PLANT PROCUREMENT AND SUPPLY

It is recommended that preference for supply be given to Nursery Industry Accreditation Scheme of Australia accredited nurseries. The accreditation provides an audited best practice system for production nurseries that ensures high quality plant stock.

Pre-order and lead times

The lead time and pre-ordering of stock is critical to ensure availability of quality stock at time of planting. As an example, 25 litre plants typically take 12-18 months to grow, larger plants require even longer lead times. Even tube stock/starter plants can require 12 months lead time due to constraints of seeding times, seed availability and species selection.

Issues around delays in construction projects provides many examples where plant stock has been held by nurseries for extended times which has led to the supply of stock that has been compromised by extended holding time. End users need to know tree stock has a use-by date and contracts for supply need to state these dates and put financial liability for unused, no longer suitable, ordered stock on the end user. Specifications around *AS 2303-2015 Tree Stock for Landscape Use*, in particular relating to container type, growing media and pruning/form need to be clear and adhered to by suppliers and enforced by end users. High tree quality according to *AS 2303-2015 Tree Stock for Landscape Use* should be the expectation of all end users. It is noted that a lack of alternative quality stock regularly forces end users to use poor quality stock.

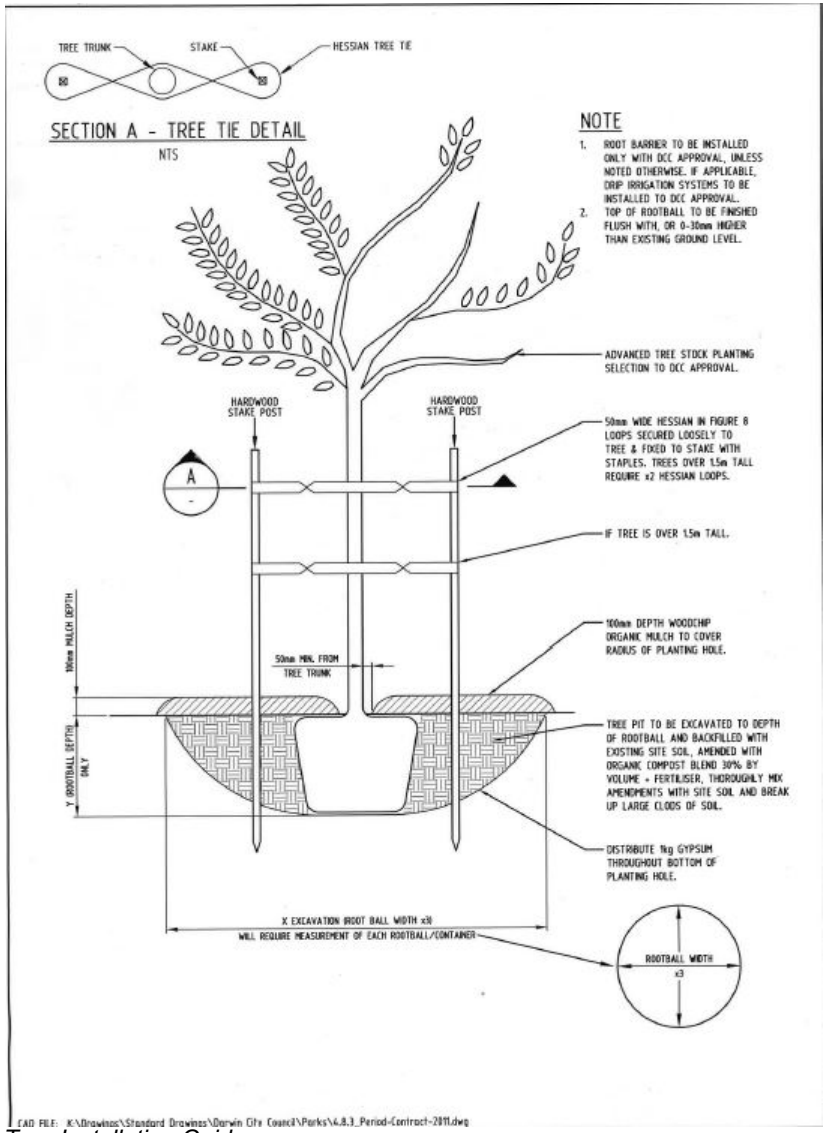
There is a need for limited quantities of high-quality stock of a pre-determined species list to be available at other times. The City of Darwin should continue with the contract for the supply of container grown trees.

Planting

Planting sizes (initial impact v long term viability)

Current research shows that smaller propagation container size produces a better outcome over larger containers. Research has also supported that air root pruning, regardless of propagation container size will produce superior quality stock.

Smaller plants are more prone to theft, vandalism, lawn mower/whipper snipper damage though it was noted that DIPL are getting good results with tube stock if in association with appropriate plant protection. City of Darwin has found that 25-50 litre propagation container size has been the most successful planting size.



Tree Installation Guide

TREE INSTALLATION

Tree planting specification – Turf/Garden areas

Tree planting in turf/Garden areas should be in accordance with the standard drawing below. Tree planting holes should be three times the diameter of the tree root ball and of the same depth. Root barrier or other impediments to lateral root growth must not be used at any time. Planting holes shall be excavated to ensure the sides of the hole are not glazed, compacted or otherwise hardened, as this has the effect of guiding the tree roots around the edge of the planting hole, causing circled and girdling roots which will have a negative effect on the trees long term resilience to high wind events.

Tree pit considerations – Size, volume, soil types, soil microbiome, drainage in urban landscapes

Ensure the maximum soil volumes possible but with minimum soil volumes specified. Industry publications and scientific findings in relation to both canopy diameters and recommended minimum soil volumes for tree rooting capacity can assist to provide specification to tree pit size and soil volume requirements for urban trees. Details are provided in Appendix E.

The Australian Standard *AS 4419-2003 Soils for Landscaping and Garden Use* should be followed with the use of “Sandy Loam” in the tree pit. The incorporation of humates and beneficial microbes prior to planting has been shown to be beneficial and can reduce the need for further fertilising.

Tree pits should be connected to stormwater or natural drainage. Woodchip mulch is preferable to paving and tree grates are preferable to permeable paving within 1500mm of tree trunks. The maximum area possible of permeable surface treatment over the structural root zone is preferred to facilitate water ingress and gas exchange.


In Ground Irrigation

Irrigation, water harvesting

In-ground irrigation is preferred over manual irrigation. Water truck irrigation is available. Drip irrigation can supply the recommended volumes. Whichever irrigation method is used watering should deliver a suitable volume of water in such a way that it penetrates the soil profile to a depth of at least 450mm.
Trees in hardscapes require watering each dry season.

The City of Darwin shall undertake a continuous 6-month watering program over the first 3 years following installation of any tree to irrigate installed trees. The works program schedule should be provided by the City of Darwin to staff and contractors engaged in watering trees. Due to varying climatic conditions, alteration of the start/finish time of the watering program and any additional watering may be advised.

Trees are to be watered via water truck or by drip line irrigation during the first three years following planting, with the following frequency:

- Three (3) times per week for the first Four (4) weeks only, after the planting date.
- Three (3) times per week for the duration of the first dry season (May 1st – October 31st)
- Two (2) times per week for the duration of the second dry season (May 1st – October 31st)
- Once (1) times per week for the duration of the third dry season (May 1st – October 31st)

At each watering event in the first-year irrigation supplied should match the volume of the container the tree was in prior to planting, for example:
25 litre tree = 25 litres per water
50 litre tree = 50 litres per water

In years 2 and 3, water volume should be a minimum of 30 litres per tree, per water event. The tree watering program should be carried out utilising qualified horticulturalists and used as an opportunity to identify issues such as pruning and pest and disease outbreak.

Trees and Services

Stormwater harvesting using storm water collection inlets should be installed wherever possible, and mandatory within the CBD. Water sensitive urban design options that relate to Darwin rainfall patterns can be considered to create a water bank, reduce runoff and optimise tree performance. Where tree pits utilise stormwater harvesting, they should also be connected to the stormwater system to ensure positive drainage is retained in tree pits to prevent waterlogging.

Working around services

It is acknowledged that trees are essential in the CBD despite potential conflict with services. A design review involving all stakeholders would facilitate infrastructure and tree coexistence. Such a review would be particularly relevant to nature strip situations and should maximise and optimise uninterrupted soil volumes and crown space for tree establishment.

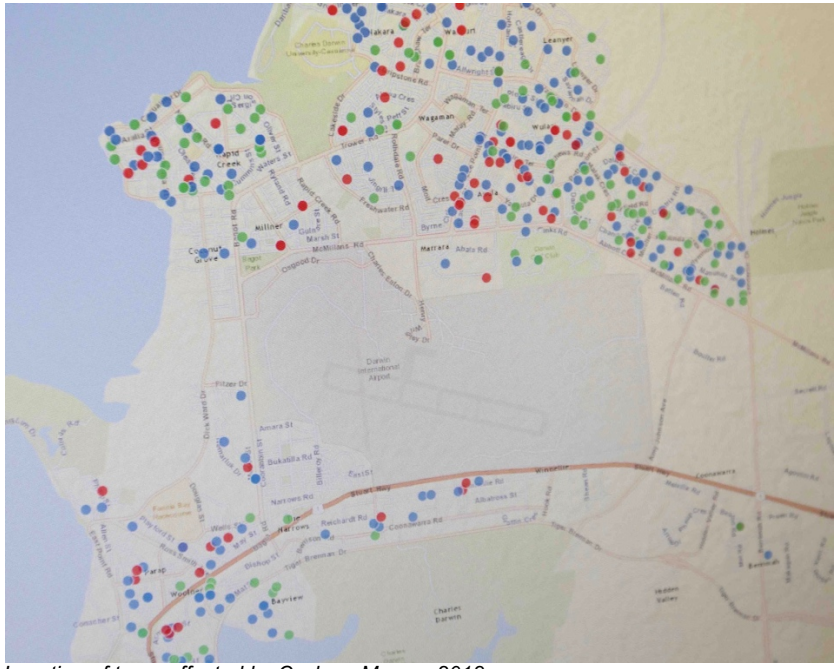
Conflict with services could be reduced by:

- Locating CBD trees in the road pavements where space in verges is restricted due to underground services or other constraints.
- Referring to the relevant service authority requirements for clearances.
- Consolidating services on one side of the street. In many suburban streets overhead lines are down one side of the road, water and sewer down the other making conflict with trees inevitable.
- Mapping high priority power/water infrastructure and ensure plantings will not interfere with main delivery lines under any circumstances.
- Defining an acceptable level of risk to infrastructure.
- Using a tree valuation method to realistically compare values with infrastructure costs.

Maintaining the Urban Forest

Establishment (Year 3) including fertilising program and formative pruning

- A fertiliser program for new plantings should be developed that provides 2 applications annually of a suitable fertiliser and 2 applications during the dry season of an appropriate soil wetting agent.
- Where possible, it is preferable to provide fertiliser and wetting agents by means of liquid application, via a water truck. Granular products may be used where necessary.
- Each tree should be mulched as per the planting specification at least once annually or as required using high quality, aged woodchip mulch with a maximum of 10% fine particles (10mm in diameter)
- Formative pruning shall be undertaken annually, and pruning must be in accordance with *AS 4373-2007 – Pruning of amenity trees*.
- Pests and diseases will be treated as required to ensure trees remain healthy and establish to their full potential.



Location of trees affected by Cyclone Marcus 2018

WHOLE OF LIFE TREE MANAGEMENT

Tree data base and data collection

The use of a data base to systematically inventory park and street tree assets is recommended and it is noted that City of Darwin has made progress in this aspect. There needs to be a systematic approach to ensure all Council areas are covered. It is recommended that 100% of trees in the municipality be identified and plotted over a 3 year period. There should be a programmed reassessment of every tree every 3 years. The management of the tree inventory data requires dedicated software that provides the required functionality and that can interface with other IT platforms used by City of Darwin. The committee notes that *Treeplotter* software is one option that meets City of Darwin requirements.

Such an approach will assist City of Darwin with their tree management plans. Knowing what you have, and its location is a prerequisite to manage assets in a cost effective and proactive manner. TC Marcus has provided a unique opportunity for City of Darwin to conduct an inventory as there are now many thousands less trees. The inventory data is a foundation to build operational plans and will assist City of Darwin with future planning and planting plans.

Council should also use the report on TC Marcus and its data format as a basis for gathering data following future storm/cyclone events. An additional data field that should be included in future reports is to record observations on why an individual tree has failed e.g. root damage, poor pruning, disease etc. Several Council officers and arborists should be trained and allocated for emergency operational data gathering with adequate resources to react promptly following an event. Accumulating information in such a way and conducting regular reviews of this report and the associated tree lists every 3 years or after a significant storm event will continue to improve the cyclone resilience of tree plantings in Darwin.

Increasing Canopy Cover

The tree inventory, data base and resultant improved planning will facilitate a shift from reactive tree management to a proactive modern urban forest model which will result in fewer customer requests, better tree health and structure and more cost-effective operations.

Ongoing maintenance and associated funding – trees are a valuable community asset

If mature trees are properly valued, then the decision making for works in proximity to trees becomes a straight forward cost benefit analysis. The cost of activities such as realigning irrigation trenches or design and placement of footpaths can then be compared with the properly assessed value of a mature tree which may be in the tens of thousands of dollars. Added to that value can be the assessment of damage to infrastructure should the works compromise the tree stability in a future storm event.

There are tools for valuing trees in an urban setting and a good example that is relatively simple to use is the system developed by the City of Melbourne.
https://www.melbourne.vic.gov.au/SiteCollectionDocuments/Tree-valuations.DOC

The committee recommends that City of Darwin should review the current resource allocation concerning tree management and its ability to provide a satisfactory level of service to the Councils tree assets, and community's tree population.

City of Darwin should actively manage the loss of trees in the municipality to maintain and increase current canopy cover levels in public open space to a minimum of 50% by 2030.


Tree Management

The committee recommends that City of Darwin should review all tree related policy and process and assess for their ability to meet the organisational requirements for tree risk management, tree condition assessment, tree removal, tree retention, tree replacement and development consent, and for their performance against contemporary best practice urban forest management models and existing/future strategic outcomes. A citywide, long-term Strategic Urban Forest Management Plan is required.

Following the endorsement of this report and any recommendations that are accepted by council the *Tree Management Plan* should be reviewed to ensure that the *Tree Management Plan* accurately reflects the findings of this report and any recommendations endorsed by council.

Irrigation/ supplementary watering

Watering regimes for the first 3 years are discussed under the Tree Establishment section. After 3 years most, trees should be sufficiently established to survive without additional watering. There may be locations where additional watering is needed but this should be assessed on a case by case basis.

City of Darwin in conjunction with other stake holders should investigate the use and installation of storm water collection inlets for storm water harvesting and watering of street trees.

Pruning

For long term management of trees *AS4373 Pruning of Amenity Trees* is recommended.

Monitoring/ risk management/ acceptable risk thresholds

The community needs to understand and have an expectation and acceptance of tree failure(s) during cyclonic and major storm events; it is inevitable.

Tree Management

Therefore, a tree risk threshold needs to be defined and understood by the community and this may require some effort in community education. What level of tree risk is acceptable and what level is not, and what level of risk requires intervention. In the development of risk thresholds there must be a consideration of cyclonic strength wind events. This should be balanced by the demonstrable benefits that trees provide during cyclonic events. A tree risk inspection program that identifies and consequently mitigates tree risk to avoid or reduce exposure to legal liability claims is integral to such a risk management strategy.

It is recommended City of Darwin adopts an industry standard, peer reviewed, tree risk assessment system. The International Society of Arboriculture Tree Risk Assessment Qualification (TRAQ) method (Dunster 2017) and the Quantified Tree Risk Assessment system (QTRA 2018) are two methods worth considering. A tree risk assessment system would be used to develop risk thresholds and points where intervention is required and lead to a balanced and proportionate tree risk management approach.

Tree protection

The management and care of the below ground portion of a tree is as important as the management of the above ground portion. If tree roots are not protected, then it is irrelevant what species are planted. Damage to large portions of any tree root system will compromise the tree and contribute significantly to instability and uprooting in a storm event.

There is an Australian Standard - *AS4970-2009 on Protection of Trees on Development Sites*. This should be followed but more importantly Council should consider mechanisms to enforce tree protection. One effective means to protect public trees could be achieved by integrating the requirements *of AS4970-2009 Protection of Trees on Development Sites* into council development processes.

Tree Management

AS4970-2009 should be incorporated into City of Darwin council's works permit system. Works within 3 meters of any tree less than 5 meters in height, or within the Tree protection zone of any tree greater than 5 meters in height must have a works permit issued, with conditions in place to ensure the protection of the tree as per the standard in place. City of Darwin should encourage all other NT government departments to follow suit.

The committee recommends that Council should review existing measures in other LGA's such as by-laws, Tree Protection Orders, Vegetation Protection overlays, tree removal/pruning permit systems, development consent requirements and the associated need for resourcing of such systems, including enforcement and surveillance. The establishment of a bond on tree assets for protection has been used by City of Darwin during construction of the Raintree Park upgrade. The implementation and success of this should be reviewed by Council as a possible option for all construction activities in proximity of trees on Council land.

Education

It is recommended that City of Darwin develop and deliver tree management education programs to tree management staff, tree workers, parks crews, all contractors, (including irrigation), development assessment staff, customer service staff, high level decision makers and the wider community. This would include educating all stake holders on the importance of the recommendations in this document and the repercussions if these guidelines are not adhered to.

Gardens Road

Conclusion

Darwin needs its urban forest as the effects of climate change, the need to attract and retain population and tourism continue to grow. Adoption by City of Darwin of the full cycle of tree management recommended in this report, assists City of Darwin to retain and increase its urban forest well into the future, even in the event of cyclones such as Marcus 2018.

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AS 4419-2003 Soils for landscaping and garden use. https://www.standards.org.au/standards-catalogue/sa-snz/consumer/cs-037/as--4419-2003

AS 4970-2009 Protection of trees on development sites. https://www.standards.org.au/standards-catalogue/sa-snz/agriculture/ev-018/as--4970-2009

APPENDICES

APPENDIX A

PREFERRED TREES FOR DARWIN

A tree with low cyclone resilience may have an attribute such as form, colour, wildlife attractant that is desirable in a specific location. Where these trees are small, such as many Grevilleas and Acacias, and unlikely to cause damage in the event of uprooting, they have been included in Appendix A.

Similarly, trees that have been recognised as having a medium cyclone resilience because of issues with branch drop or trunk splitting are included here. The use of these species needs to be tempered by an understanding of their performance in storm events and careful consideration of the planting location.

Genus Name	Species Name	Common Name	Origin	Cyclone resilience
Acacia	dunnii	Elephant Ear Wattle	NT Native	Low
Acacia	torulosa		NT Native	Low
Acacia	latescens		NT Native	Medium
Adansonia	gregorii	Boab	NT Native	High
Adansonia	digitata	African Boab	Exotic	Medium
Adenanthera	pavonina	Red Bead Tree	NT Native	Medium
Aidia	racemosa	Archer Cherry	NT Native	High
Albizia	lebbeck	White Siris	NT Native	Medium
Albizia	saman	Rain Tree	Exotic	Medium
Allosyncarpia	ternata	Allosyncarpia	NT Native	Medium
Alphitonia	excelsa	Red Ash	NT Native	Medium
Alstonia	actinophylla	Northern Milkwood	NT Native	High
Antidesma	ghaesembilla		NT Native	High
Araucaria	cunninghamii subsp. cunninghamii	Hoop pine	Australian Native	Medium
Archontophoenix	alexandrea	Alexandra Palm	Australian Native	High

Genus Name	Species Name	Common Name	Origin	Cyclone resilience
Arfeuillea	arborescens	Hop Tree	Exotic	High
Asteromyrtus	magnifica		NT Native	High
Asteromyrtus	symphyocarpa	Liniment Tree	NT Native	High
Banksia	dentata		NT Native	High
Barringtonia	asiatica	Poison tree	Exotic	High
Barringtonia	acutangula	Freshwater Mangrove	NT Native	Medium
Bauhinia	variegata	Purple Bauhinia	Exotic	Low
Berrya	cordifolia	Trincomalee	Exotic	Inconclusive
Bismarkia	nobilis	Bismark Palm	Exotic	Medium
Bombax	ceiba	Kapok Tree	NT Native	High
Brachychiton	diversifolius	Kurrajong	NT Native	High
Brachychiton	rupestris		Australian Native	Inconclusive
Brownea	spp.		Exotic	Medium
Browneopsis	ucayalina		Exotic	High
Buchanania	arborescens	Little Gooseberry Tree	NT Native	High
Buchanania	obovata	Green Plum	NT Native	High
Caesalpinia	ferrea	Leopard Tree	Exotic	Medium
Callistemon	viminalis	Weeping Bottlebrush	Australian Native	High
Callitris	intratropica	Northern Cypress Pine	NT Native	High
Calophyllum	inophyllum	Beauty Leaf	NT Native	High
Calophyllum	sil		NT Native	High
Canarium	australianum	Melville Island White Beech	NT Native	High
Carallia	brachiata	Bush Current	NT Native	High
Cassia	nodosa	Rainbow Shower	Exotic	High
Castanospermum	australe	Black Bean	Australian Native	High
Casuarina	equisetifolia	Coastal She-Oak	NT Native	Medium
Casuarina	papuana		Exotic	Medium

Genus Name	Species Name	Common Name	Origin	Cyclone resilience
Casuarina	cunninghamiana	Riverine Casuarina	NT Native	Inconclusive
Celtis	philippensis		NT Native	High
Citharexylum	spinosum	Fiddlewood	Exotic	Medium
Citrus	latifolia	Lime	Exotic	High
Clerodendrum	floribundum	Clerodendrum	NT Native	Medium
Coelospermum	reticulatum		NT Native	Low
Cordia	subcordata	Kerosene Wood	NT Native	Medium
Corymbia	ptychocarpa	Swamp Bloodwood	Australian Native	Medium
Corymbia	polycarpa	Long-Fruited Bloodwood	Australian Native	Medium
Corymbia	bleeseri	Smooth stemmed bloodwood	NT Native	Medium
Corymbia	jacobsiana	String Barked Bloodwood	NT Native	Medium
Corymbia	arnhemensis	Katherine Gorge Bloodwood	NT Native	Medium
Corymbia	papuana	Ghost Gum	Australian Native	Medium
Corymbia	polysciada	Apple Gum	NT Native	Medium
Corymbia	bella	Ghost Gum/White Gum	NT Native	Medium
Cupaniopsis	anacardioides	Tuckeroo	NT Native	High
Cyclophyllum	schultzii	Canthium	NT Native	High
Denhamia	obscura	Denhamia	NT Native	High
Dillenia	alata	Red Beech	NT Native	Medium
Dillenia	indica	Elephant Apple	Australian Native	Medium
Diospyros	compacta	Australian Ebony	NT Native	High
Diospyros	maritima	Broad Leaved Ebony	NT Native	High
Diospyros	nigra	Black Sapote	Exotic	Medium
Dodonea	platyptera	Hop Bush	NT Native	Low
Dypsis	lutescens	Golden Cane	Exotic	High
Dypsis	madagascariensis	Malagasy Palm	Exotic	High

Genus Name	Species Name	Common Name	Origin	Cyclone resilience
Elaeis	guineensis	African Oil Palm	Exotic	High
Erythrina	variegata	Coral tree	NT Native	Medium
Erythrophleum	chlorostachys	Ironwood	NT Native	High
Eucalyptus	apodophylla	White bark	NT Native	High
Eucalyptus	alba	White Gum/Salmon Gum	NT Native	Medium
Eucalyptus	herbertiana	Herbert's Gum	NT Native	High
Eucalyptus	nesophila	Melville Island Bloodwood	NT Native	High
Eucalyptus	bigalerita	Northern Salmon Gum	NT Native	Medium
Eucalyptus	miniata	Darwin Woollybutt	NT Native	Medium
Eucalyptus	oligantha	Broad-leaved Box	NT Native	Medium
Eucalyptus	phoenicea	Scarlet Gum	NT Native	Medium
Eucalyptus	tectifica	Darwin box	NT Native	Medium
Eucalyptus	tetrodonta	Northern Stringybark	NT Native	Medium
Eucalyptus	tintinnans	Hills Salmon Gum	NT Native	Medium
Fagraea	racemosa	Fagraea	NT Native	Inconclusive
Ficus	scobina	Sandpaper Fig	NT Native	High
Ficus	virens	Banyan	NT Native	High
Ficus	coronulata	Peach-Leaf Fig	NT Native	High
Ficus	opposita	Sandpaper Fig	NT Native	High
Ficus	racemosa	Cluster Fig	NT Native	High
Ficus	rubignosa	Port Jackson Fig	Australian Native	Medium
Ficus	longifolia	Narrow Leaf Fig	Exotic	Medium
Ficus	brachypoda	Rock fig	NT Native	Inconclusive
Ganophyllum	falcatum	Scaly Ash	NT Native	Medium
Gardenia	megasperma		NT Native	High
Gardenia	fucata		NT Native	Medium
Grevillea	angulata	Holly Leaf Grevillea	NT Native	High

Genus Name	Species Name	Common Name	Origin	Cyclone resilience
Grevillea	heliosperma	Rock Grevillea	NT Native	High
Grevillea	parallela	Silver Oak	NT Native	Low
Grevillea	pteridifolia	Fern-Leaved Grevillea	NT Native	Low
Grevillea	refracta	Silver-Leaf Grevillea	NT Native	Medium
Grevillea	decurrens	Clothes-peg Tree	NT Native	Medium
Helicia	australasica	Helicia	NT Native	Inconclusive
Hibicus	tiliaceous	Beach Hibiscus	NT Native	Medium
Hibicus	tiliaceous var. rubra	Red Beach Hibiscus	NT Native	Medium
Horsefieldia	australiana	Nut Horsfieldia	NT Native	High
Hydriastele	wendlandiana	Florence Falls Palm	NT Native	High
Hyophorbe	verschaffeltii	Spindle palm	Exotic	High
Jacksonia	dilatata	Jacksonia	NT Native	High
Kigelia	pinnata	Sausage Tree	Exotic	High
Lagerstroemia	indica	Crepe Myrtle	Exotic	High
Lagerstroemia	speciosa	Pride Of India	Exotic	Medium
Latania	loddigesii	Blue Latan Palm	Exotic	High
Leptospermum	madidum	Weeping Tea Tree	NT Native	High
Licuala	ramsayii	Queensland Fan palm	Australian Native	High
Livistona	benthamii	Benthams Fan Palm	NT Native	High
Livistona	humilis	Sand Palm	NT Native	High
Livistona	inermis	Whispy Fan Palm	NT Native	High
Livistona	mariae subsp. rigida	Mataranka Fan Palm	NT Native	High
Livistona	muelleri	Northern Cabbage Palm	Australian Native	High
Lophostemon	grandiflorus subsp. riparius	Northern Swamp Box	NT Native	High
Lophostemon	lactifluus	Swamp box	NT Native	High
Lyrata	pandurata	Fiddleleaf fig	Exotic	Inconclusive
Mangifera	indica	Mango	Exotic	Medium

Genus Name	Species Name	Common Name	Origin	Cyclone resilience
Maniltoa	lenticellata	Silk handkerchief tree	Australian Native	High
Maranthes	corymbosa	White Cloud Tree	NT Native	High
Melaleuca	leucadendra	Weeping Paperbark	NT Native	High
Melaleuca	argentea	Silver-Leaved Paperbark	NT Native	High
Melaleuca	bracteata	Black tea tree	NT Native	High
Melaleuca	cajuputi	Paperbark	NT Native	High
Melaleuca	dealbata	Paperbark	NT Native	High
Melaleuca	minutifolia	Paperbark	NT Native	High
Melaleuca	nervosa	Fibrebark	NT Native	High
Melicope	elleryana	Euodia	NT Native	Low
Micromelum	minutum		NT Native	High
Miliusa	brahei	Miliusa	NT Native	High
Millettia	pinnata	Indian Beech	NT Native	Medium
Mimusops	elengi (cultivated)	Mimusops Red Condoo	Exotic	High
Mimusops	elengi (NT natve)	Mimusops	NT Native	High
Mimusops	elengi cv. Street Elegance	Mimusops "Street elegance"	Exotic	High
Monoon	australe	Northern Territory Polyalthia	NT Native	Medium
Morinda	citrifolia	Rotten Cheesefruit	NT Native	High
Myoporum	acuminatum	Boobialla	Australian Native	Inconclusive
Myristica	insipida	Wild Nutmeg	NT Native	High
Nauclea	orientalis	Leichardt Tree	NT Native	High
Peltophorum	pterocarpum	Yellow Flame Tree	NT Native	Medium
Persoonia	falcata	Milky plum	NT Native	High
Petalostigma	pubescens	Quinine Tree	NT Native	High
Phaleria	clerodendrum	Butterfly Tree/Scented Daphne	Australian Native	High

Genus Name	Species Name	Common Name	Origin	Cyclone resilience
Pittosporum	moluccanum		NT Native	Medium
Pittosporum	angustifolium	Native Apricot	NT Native	Inconclusive
Planchonia	careya	Cocky Apple	NT Native	High
Pleiogynium	timoriense	Burdekin plum	Australian Native	High
Plumeria	obtusa	Singapore Frangipani	Exotic	High
Plumeria	rubra	Frangipani	Exotic	High
Polyalthia	longifolia	Polyalthia	Exotic	Medium
Polyalthia	longifolia subsp. pendula	Indian Mast Tree	Exotic	Medium
Pterocarpus	indicus	PNG Rosewood	Exotic	Medium
Ptychosperma	macarthurii	Macarthur palm	NT Native	High
Roystonea	regia	Cuban Royal Palm	Exotic	Medium
Saraca	spp.		Exotic	Medium
Schefflera	actinophylla	Umbrella Tree	NT Native	Medium
Schleichera	oleosa	Ceylon Oak	Exotic	High
Staphylea	pinnata	European Bladdernut	Exotic	Medium
Sterculia	quadrifida	Peanut Tree	NT Native	High
Sterculia	holtzei		NT Native	Inconclusive
Syzygium	forte	White Bush Apple	NT Native	High
Syzygium	nervosum	Daly River Satinash	NT Native	High
Syzygium	suborbiculare	Red Bush Apple	NT Native	High
Syzygium	minutuliflorum	Gove Satinash	NT Native	Medium
Syzygium	armstrongii	Bush Apple	NT Native	High
Syzygium	fibrosum	Small Red Bush Apple	NT Native	High
Syzygium	cumini	Java Plum	Australian Native	Low
Syzygium	angophoroides	Satinash	NT Native	Medium
Syzygium	jambos	Rose Apple	Exotic	Inconclusive
Syzygium	eucalyptoides subsp. eucalyptoides		NT Native	High

Genus Name	Species Name	Common Name	Origin	Cyclone resilience
Tabebuia	aurea	Silver Trumpet Tree	Exotic	Medium
Tabebuia	rosea	Rosy Trumpet Tree	Exotic	Medium
Tabebuia	pallida	Pink Trumpet Tree	Exotic	Medium
Tabebuia	palmerii		Exotic	Medium
Tabernaemontana	orientalis	Iodine bush	NT Native	High
Tamarindus	indica	Tamarind	Exotic	High
Tectona	grandis	Teak	Exotic	Medium
Terminalia	ferdinandiana	Billy Goat Plum	NT Native	High
Terminalia	microcarpa	Damson Plum	NT Native	High
Terminalia	catappa	Indian Almond	NT Native	High
Terminalia	platyphylla	Wild Plum	NT Native	Medium
Terminalia	arostrata	Nutwood	NT Native	Inconclusive
Terminalia	belliricia	Bahera	Exotic	Inconclusive
Terminalia	melanocarpa		Australian Native	Inconclusive
Timonius	timon	Tim-Tim	NT Native	High
Veitchia	merillii	Manilla palm	Exotic	High
Vitex	glabrata		NT Native	Inconclusive
Wrightia	pubescens	Wrightia	NT Native	Low
Xanthostemon	paradoxus	Bridal Tree	NT Native	High
Xanthostemon	chrysanthus	Golden Penda	Australian Native	High

APPENDIX B

TREES RECOMMENDED NOT TO BE PLANTED

Most of the species with a low cyclone resilience have been recommended to be avoided in plantings in Darwin. In addition, there are species that are highly cyclone resilient but are not recommended for planting in particular locations for other reasons such as being allergenic/poisonous, are invasive, or have nuisance fruit. These species are also included here in Appendix B.

Genus Name	Species Name	Sub species	Common Name	Notes
Acacia	auriculiformis		Black Wattle	Low cyclone resilience and high risk to property and life
Alstonia	scholaris		White Cheesewood	Highly allergenic
Artocarpus	altilis		Breadfruit	Large dangerous fruit
Artocarpus	heterophyllus		Jackfruit	Large dangerous fruit
Averrhoa	carambola		Star Fruit	Environmental weed
Azadirachta	indica		Neem	Declared weed
Carpentaria	acuminata		Carpentaria Palm	Caustic fruits
Caryota	spp.		Fishtail Palm	Low cyclone resilience and environmental weed
Cascabela	thevetia		Yellow Oleander	Low cyclone resilience and environmental weed
Cassia	fistula		Golden Shower	Environmental weed
Cassia	siamea		Siamese cassia	Environmental weed
Cocos	nucifera		Coconut Palm	Large dangerous fruit
Delonix	regia		Poinciana	Environmental weed
Eucalyptus	camaldulensis		River Red Gum	Low cyclone resilience and high risk to property and life

Genus Name	Species Name	Common Name	Origin	Cyclone resilience
Ficus	benjamina		Weeping Fig	Low cyclone resilience and high risk to property and life
Ficus	microcarpa	hillii	Hill's Weeping Fig	Low cyclone resilience and high risk to property and life
Gauzuma	ulmifolia		West Indian Elm	Environmental weed
Gmelina	arborea		Gmelina	Environmental weed
Khaya	senegalensis		African Mahogany	Low cyclone resilience and high risk to property and life
Khaya	grandifoliola		Big Leaf Mahogany	Low cyclone resilience and high risk to property and life
Khaya	nyasica		African Mahogany	Low cyclone resilience and high risk to property and life
Psidium	guajava		Guava	Environmental weed
Pterocarpus	indicus	pendula	Weeping Rosewood	Low cyclone resilience and disease prone
Spathodea	campanulata		African Tulip	Low cyclone resilience and environmental weed
Wodyetia	bifurcata		Fox Tail Palm	Low cyclone resilience and high risk to property and life

APPENDIX C
TREE SELECTION MATRIX (TEMPLATE)

Family Name

Genus Name

Species Name

Sub species Name

Common Name

Overall Species rating – select from ‘Preferred’, ‘Not to be planted’

Origin – select from ‘NT Native’, ‘Australian Native’, ‘Exotic’

Cyclone resilience – select from ‘High’, ‘Medium’, ‘Low’, ‘Unknown’

Cyclone Resilience source – select from ‘Marcus report’, ‘Yasi Report’, ‘Tracy report’, ‘Committee consensus’, ‘Personal observation’

Climate change resilience – select from ‘High’, Medium’, ‘Low’, ‘Unknown’

Species Leaf Type – select from ‘Evergreen’, ‘Deciduous’

Form – select from ‘Large tree (excurrent)’, ‘Large tree (decurrent)’, ‘Medium tree (excurrent)’, ‘Medium tree (decurrent)’, ‘Small tree (excurrent)’, ‘Small tree (decurrent)’, ‘Shrub’

Growth Rate – select from ‘Fast’, ‘Moderate’, ‘Slow’, ‘Unknown’

Longevity – select from ‘>50 years’, ‘20 - 49 years’, ‘10 - 19 years’, ‘<10 years’, ‘Unknown’

Height - meters

Spread - meters

References

Habitat – select from ‘Wet rainforest’, ‘Dry Rainforest’, ‘Eucalypt woodlands’, ‘Savannah’, ‘Coastal Wetlands’, ‘Riparian forest’

Succession category – select from ‘Pioneer’, ‘Intermediate’, ‘Climax’, ‘Unknown’

Suitable for large parks – select from ‘Suitable’, ‘Unsuitable’

Suitable for small parks – select from ‘Suitable’, ‘Unsuitable’

Suitable for road reserves – select from ‘Suitable’, ‘Unsuitable’

Suitable for Urban landscapes – select from ‘Suitable’, ‘Unsuitable’

Suitable for drainage swales – select from ‘Suitable’, ‘Unsuitable’

Irrigation requirement – select from ‘Dryland’, ‘Turf Irrigation’, ‘Deep watering’

Weed Status – select from ‘Non-invasive’, ‘Invasive – Undeclared’, ‘Declared Class A+C’, ‘Declared Class B+C’, ‘Unknown’

Notes

A further series of attributes are potentially useful and could be added to the selection matrix to aid in species selection. The following Table lists those attributes for consideration. However, for many of these attributes there are no or little data available particularly for native Top End trees. These attributes are listed primarily as an indication for future research.

Tree Species Additional Selection Criteria

- Water requirement (Drought tolerance)
- Water requirement (Waterlogging tolerance)
- Soil compaction tolerance
- Soil Ph. requirement
- Soil Volume requirement
- Soil Elements requirement
- Heat tolerance (temperature)
- Wind tolerance
- Pollution tolerance
- Light requirement (Shade tolerance)
- Mature Crown Size (Canopy cover potential)
- Paved Area tolerance
- Past Urban Performance (Adaptability)
- Shade Density
- Mature Crown Form
- Maintenance requirements
- Tree litter production
- Pathogen and pest susceptibility
- Allergen potential
- Power line (overhead) proximity suitability
- Stock quality
- Stock availability
- Aesthetic/Flowering attributes

APPENDIX D

PLANT PROCUREMENT CONTRACT TEMPLATE

CITY OF DARWIN – TREE PROCUREMENT SPECIFICATIONS
SINGLE PROJECT – SUPPLY OF PLANTS/TREES

Trees are generally the most visible element in the landscape. They are both living organisms and potentially very large structures that may live for many decades or even centuries.

It makes sense that trees that are ordered from growers should be of the best possible quality to ensure that they establish and succeed in the landscape. Money well spent at the early stages of a landscape project assists in more rapid returns on investment.

One of the most common reasons for the failure of newly planted trees to grow and establish in the landscape is poor quality stock, especially below ground. Girdled and kinked root systems limit the ability of the tree to take up water and nutrients and may provide inadequate support. Stems with inadequate taper cannot support themselves and encourage the use artificial supports such as stakes and ties. Tall plants in undersized containers generally have insufficient root volume to support them both biologically and physically.

Growing quality trees takes skill and care. Trees are living organisms that respond uniquely to their growing environment, including that of the nursery. Plants grown in containers can quickly reach their ‘use by date’ and must be sold, planted or potted-on to remain viable. Unlike manufactured items, they cannot be stored indefinitely and there will always be a degree of variability between even the most closely specified trees.

It is important to note that well-grown trees in themselves are not a guarantee of success in the landscape. The quality of trees is only one part of the process and must be combined with good planning and design, appropriate species selection, correct planting and establishment techniques and ongoing maintenance.

The majority of this Tree Procurement Contract’s Specifications are derived from *Specifying Trees: a guide to assessment of tree quality* by Ross Clark, published in 2003 by NATSPEC/Construction Information, Milsons Point. It is based on extensive measurement and assessment of nursery-grown trees.

CONDITIONS OF CONTRACT

CONTAINER TYPE AND PRODUCTION SPECIFICATION

All trees included in this growing contract are to be grown throughout all stages in 3 dimensional air root pruning containers. Standard smooth walled pots are not acceptable for this contract. Exact pots to be used are to be agreed to by City of Darwin prior to contract commencement.

Propagation from seed/cutting in seed trays is permissible, but production methods must have strict quality control mechanisms when pricking out to ensure no J-rooting or other root defects occur.

Potting-on of trees throughout various pot sizes throughout the production phase must be conducted during optimal root colonisation periods. Where possible, pot directly into the largest pot practical for plant growth and uninterrupted root development. Girdling roots or unconsolidated rootballs will not meet the required quality standard, and will be rejected.

Potting media is to conform with AS 3743-2003.

ABOVE GROUND STANDARD

The above ground qualities of a landscape tree are what is seen by the client, and generally what the trees will be judged on by the public. Maintaining an aesthetically pleasing crown, branches, and stem provides a desirable outcome. Correct nursery production of crown, branch and stem can also provide improved health, improved safety, and longer life expectancy to landscape trees.

The above-ground quality shall comply with the following requirements:

True to type

Individual trees and batches shall be clearly labelled. Correct botanical nomenclature is preferred.

Health and vigour

(a) *Health*—Foliage size, texture and colour at time of delivery shall be consistent with the size, texture and colour shown in healthy specimens of the nominated species.

(b) *Vigour*—Extension growth shall be consistent with that exhibited in healthy specimens of the species nominated.

Pest and disease

In general, trees shall show no evidence of pests or disease. However, a small amount of insect attack is common for native species (as they grow with their native pests).

Injury

Trees shall be free from injury, such as: damage caused by ties, stakes and labels, sunburn, rough handling or storms.

Self-supporting

Trees shall be self-supporting without the mechanical support of stakes/ties.

Stem taper

The stem diameter at any given point on the stem shall be greater than the stem diameter at any higher point on the stem.

Pruning

Pruning practices in the nursery impact on the aesthetics, the structural integrity or the health of the tree. It is important that pruning practices benefit the tree's development.

(c) All pruning shall be clean-cut at the branch collar.

(d) Any pruning has been carried out in such a way as to allow the tree to quickly seal the pruning wound, without long-term damage to the tree. Pruning should be in compliance with 'natural target' pruning undertaken as given in AS 4373.

(e) Pruning trees just before shipment should be minimized. Tree's shall been grown to conform with a specified clear stem height requirement throughout it's production, rather than having the lower branches removed just before shipment.

(f) Stress on the trunk is reduced, healthy growth rates are maintained and adequate stem taper is maintained by not lifting the crown of the tree too high.

Apical dominance

For trees with an excurrent form, trees supplied shall have a defined central leader with the apical bud intact.

Crown symmetry

Difference in crown distribution on opposite sides of the stem axis shall not exceed 20%.

Stem structure

For trees with excurrent form, there shall be a single stem in the centre of the crown.

For trees with decurrent form, the central stem shall not be divided at any point lower than the clean stem height specified and the stem junction at the point of division must be sound.

For all trees, branch diameter should be less than or equal to one-half of the stem diameter immediately above the branch junction.

Included bark

Included bark in crotches is a common cause of structural weakness in the branch or stem junction and can result in breakages during storms. Many failures in mature trees occur as a result of increased leverage on weakly attached stems or branches.

The branch/stem bark ridges at junctions between stems and branches and between City of Darwinominant stems shall be convex.

Trunk position

To allow the development of the root system symmetrically about the trunk it is important that the trunk of the tree is in the middle of the rootball.

The distance from the centre of the trunk to the extremity of the rootball shall not vary by more than 10%. The smallest dimension must not be less than 90% of the largest dimension.

Indication of North

The correct orientation of a tree can be important to the success of that tree in its new location (i.e. ensuring that the cambium sheltered from the sun in the nursery is not exposed on planting). This is particularly important in large trees. For trees in containers larger than 100 L, the northerly aspect in the nursery must be clearly indicated in such a way as to not be erased or misplaced in transit.

BELOW GROUND STANDARD

The tree below ground (the root system) is what we do not see and specifications generally do not deal with it well, if at all. The root system, however, is just as important as the tree above ground and, as such, should receive the same amount of attention. The root system of a landscape tree must have enough overall surface area, and be sufficient to take up water and nutrients. Importantly, it must also be well structured so it can grow-on and support the tree indefinitely.
The below-ground quality shall comply with the following requirements:

Root division

Two important aspects of root division are:

Total division.

Pattern of division.

The ability of a root system to take up moisture and nutrients is directly related to the surface area of the root system, which, in turn, is directly related to root division. Roots must divide and divide again (total division). Root systems with inadequate division not only suffer from a reduced surface area but also offer too few points for new roots to develop.

Not only should roots divide repeatedly but the pattern of this division is also important. Division should be outwardly progressive (primary division) to ensure a strong structural base for any later root development. Trees held too long in containers (above ground or in-ground) may exhibit excessive non-directed division. While this may provide root surface area, it adversely impacts on root structure and makes the rootball hydrophobic.

For small trees, the entire rootball must be occupied by fibrous roots. However, for large trees it is possible to use a range of techniques in the early and intermediate stages of growth, providing that there is enough division within the rootball to support the tree adequately at the time of sale.

For trees in containers less than 45 L, roots must have undergone primary division at not more than 100 mm intervals.

For trees in containers greater than or equal to 45 L, roots within the outer 50% of the rootball must also have undergone primary division at not more than 150 mm intervals.

Root direction

Roots, from the point of initiation, should generally grow in an outwards (radial) or downwards direction. Any deviation from the established direction must not exceed 45o.

During below-ground inspection, no evidence of kinked taproots or of circling roots shall be found within the rootball.

Rootball occupancy

On shaking or handling the unsupported rootball at least 90% of the soil volume must remain intact.

Rootball depth

For trees in containers over 45 L, rootballs shall have a diameter greater than or equal to their depth.

Height of root crown

The root crown is the junction between the belowground parts and aboveground parts of the tree. Regardless of the size of the tree the root crown belongs at the surface of the rootball. Burying the root crown can lead to fungal infections, serious disruptions of the root system’s structure and function or to the death of the tree.

The root crown shall be at the surface of the rootball, and not below.

Rootball protection in transit
The combination of container and handling system shall deliver the rootball intact.

INSPECTION AND SAMPLING

All trees included in this growing contract will be subject to inspection and/or sampling.

The grower is to complete inspections at 3 monthly intervals and report to City of Darwin using the tree inspection form (see Appendix).

Prior to dispatch/shipment from grower, City of Darwin Arborist/Project Manager shall conduct an inspection using the tree inspection form (see Appendix).

Non-compliance may lead to rejection of the entire batch, and/or payment withheld for all/non-compliant individual trees from batch.

INSPECTION SAMPLING TABLE

Number of trees per batch	Number of trees to sample
0–20	1
21–50	2
51–100	4
101–500	4 for the first 100 + 2% of balance of order
501–2000	12 for first 500 + 1% of balance of order
2001+	27 for the first 2000 + 0.5% of balance of order

Inspection shall include visual assessment based on the tree inspection form criteria, and the following steps:

Step 1 Remove any stakes. If the tree is then not self-supporting, reject the tree. If the tree is self-supporting and less than 45 L, proceed to step 2. If the tree is self-supporting and greater than or equal to 45 L, proceed to step 3.

Step 2 Place the tree on a level surface ensuring that the root ball is well watered. Hold the stem at 80% of the total stem height. Bend the stem

making sure that the pressure is always at right angles to the position of the stem. The stem should be able to be bent 30° side to side without the root ball lifting off the ground (see Figure B1). If the root ball rocks such that it lifts off the ground then the root ball is too small to be able to support the tree without stakes.

Step 3 Holding the stem at 25% height above the rootball surface, rock the stem vigorously from side to side. There must be no evidence of movement of the stem within the rootball and there must be no evidence of cracks in the rootball at the edge of previous container(s). These indicate previous pottings, which were not correctly rootpruned, or a lack of root division at that point.

Step 4 Remove the tree from the container or remove the hessian or in-ground container or otherwise peel back any wrapping to expose the exterior of the rootball.1 Check that any confused or circling roots at the outside of the rootball have diameter of less than 25% of the stem diameter at ground level for trees of less than 40 mm and less than 10 mm in diameter for trees with a stem diameter at ground level of 40 mm or more. Investigative inspection usually takes two basic forms: destructive (complete) or partial.

Destructive and partial rootball inspections

With destructive rootball inspection, all of the soil from the rootball is washed away (using water or compressed air) to give a clear picture of how the root system has developed. However, as this destroys the tree destructive inspection will generally be carried out infrequently.

Where destructive inspection is deemed necessary, trees will be sacrificed. (The trees sacrificed will be in addition to the number of trees required.) The cost of these plants can either be built into the supplier's price when quoting for supply or itemised as an additional cost.

Where sacrifice of plants is a nominated expense they should be paid for:

1. By the purchaser, if the batch is found to conform.
2. By the supplier, if the batch fails to conform.

With partial rootball inspection, a section of the rootball, sufficient to enable inspection of the root development from the stem to the outer extremity of the rootball (generally a wedge-shaped section), is washed away (using water or compressed air).

Removal of a wedge-shaped section of the rootball of trees in 5-100 L sizes is generally practical. In such cases, ensure that sufficient media is removed to inspect the root development in the upper 150-200 mm of the rootball, from the stem to the extremity, and the outer section of the rootball – top to bottom.

Balance Inspection for Small trees

Balance (small trees) assessment requirements:

(a) Tubes or plant cells: height above rootball surface must be between 1.5 and 2.5 times the height of the tube or plant cell.

(b) Trees in containers < 45 L (other than tubes or plant cells) or ex-ground trees of Size Index < 57 (e.g. 1.9 m high × 30 mm calliper); height must fall within the range indicated for the container size in **Small container-grown trees table**.

(c) Containers/rootballs (other than tubes or plant cells) must remain flat on the ground when the stem, held at 80% of height above the rootball surface, is deflected 30º from the vertical, side to side.

Exempt: Species that naturally produce hard inflexible wood in the early stages of their development.

SMALL CONTAINER-GROWN TREES TABLE

Container size (or minimum rootball diameter)	Height range (m)	
	Thin stemmed species	Thick-stemmed species
Tubes or plant cells	Tree height between 1.5 and 2.5 × container height	
150 mm (1.8L)	0.4 – 0.6	0.3 – 0.5
180 mm (2.6L)	0.5 – 0.7	0.4 – 0.6
200 mm pot (4L)	0.7 – 0.9	0.6 – 0.8
200 mm bag (5L)	0.8 – 1.0	0.7 – 0.9
240 mm (8L)	1.0 – 1.2	0.8 – 1.0
300 mm (15L)	1.2 – 1.5	1.0 – 1.2
330 mm (25L)	1.5—1.9	1.2—1.6
400 mm (35L)	1.8—2.2	1.4—1.9

Balance inspection for Large trees

Balance (large trees) assessment requirements:

(g) For trees grown in containers ≥ 45 L, the Size Index must lie within the range for the nominal container size shown in the **Common container volumes – Size index range table**.

COMMON CONTAINER VOLUMES – SIZE INDEX RANGE

Size index	Nominal container volume (L)	Size index	Nominal container volume (L)
57–74	45	453–587	550
77–99	60	495–640	600
83–107	75	533–716	700
111–143	100	632–818	800
154–200	150	711–921	900
194–251	200	791–1023	1000
227–314	250	842–1089	1100
273–353	300	918–1188	1200
289–373	350	1148–1485	1500
330–427	400	1530–1980	2000
371–480	450	1913–2475	2500
412–518	500		

Size Index is an indicator of the tree's size above ground expressed as a simple number. Size Index is calculated by multiplying the height (m) by the calliper (mm, measured at 300 mm above ground), as follows:

Size Index = height (m) × calliper (mm)

APPENDIX 1. OF PLANT PROCUREMENT CONTRACT
TREE INSPECTION FORM

General	
Date	Reference/Purchase Order No.
Purchaser	
Supplier	Inspected by (supplier/purchaser/agent)
Species	Batch identification
Number of trees in batch	Container/rootball size
Height range	Calliper range
Special requirements	
Above ground	
Labelling	☐
Health and vigour	☐
Freedom from pests and disease	☐
Freedom from injury	☐
Self-supporting	☐
Stem taper	☐
Pruning	☐
Apical dominance	☐
Crown symmetry	☐
Stem structure	☐

Included bark	☐	
Trunk position	☐	
Compatibility of graft unions	☐	
Indication of north	☐	
Below ground	☐	
Inspection method used	☐	External only
	☐	External plus investigative
	☐	destructive ☐ Partial
Number of trees in sample	☐	
Root division	☐	
Root direction	☐	
Diameter nonconforming roots at rootball extremity	☐	
Rootball occupancy	☐	
Rootball depth	☐	
Height of root crown	☐	
Non-suckering rootstock	☐	
Balance		
Balance	☐	

Conformance with specification				
Conforming	☐	Yes	☐	No
Comments				

Name and signature (inspector)

Plant Schedule

Genus	Species	Quantity	Container volume (L)	Height (M)	Calliper (mm)	Supply Date	Unit Price (inc.GST)	Species Total Price (inc.GST)

APPENDIX 2. OF PLANT PROCUREMENT CONTRACT
SUPPLY OF TREES/PLANTS FOR CITY OF DARWIN PROJECT

(Standing Offer)
The Chief Executive Officer
City of Darwin
I/We the undersigned hereby offer to supply the goods as described in the attached document for the period stated and subject to the conditions/specifications prescribed herein. I/We agree to supply the goods within the delivery time and in accordance with the delivery terms stated.

Signed	
Print Name	
Date	
On Behalf of	
ABN	
Postal Address	

Telephone		**Facsimile**	

Signature of Witness	

Print Name	

Date	

APPENDIX E
TREE PLANTING SPECIFICATIONS - TREE PIT SOIL VOLUMES

Tree pit volumes should be calculated using the formula from the NATSPEC Specification for landscape trees (www.natspec.com.au) Required soil volume (m^3) = (Height (m) X DBH (mm) divided by 100.

e.g. the required soil volume for a *Mimusops elengi* would be 10(m) X 450(mm) divided by 100 = $45m^3$
In locations with constraints where the NATSPEC specified volumes cannot be met, tree pit volumes must be at least 60% of the calculated volume, or a smaller tree species should be selected.

Trees planted in turf or garden areas without physical restrictions on the growth of tree roots are exempt from this calculation.