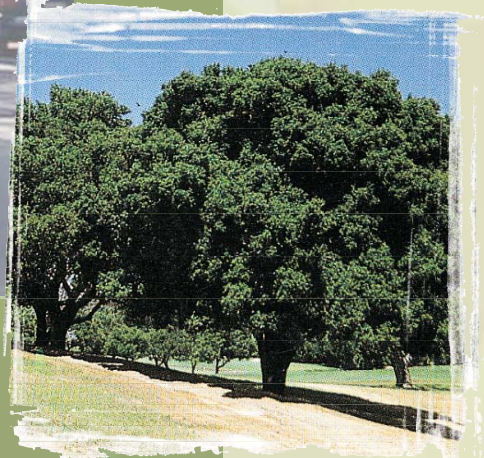


Urban Forest Guidelines



*City of Brentwood
Parks & Recreation
Department*



5/22/2002

City of Brentwood Urban Forest Guidelines



*A Document to Specify
Street Tree Species,
Planting Locations,
and Future Maintenance*

Prepared for:
City of Brentwood
708 Third Street
Brentwood, California 94513



Urban Forest Guidelines

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Appendix A: Plans and Sections for Street Types

Appendix B: Street Tree List and Photographs

Appendix C: Nursery Stock Specifications

Appendix D: Maintaining Street Trees

Appendix E: Structural Soil Specifications



INTRODUCTION

The City of Brentwood has developed these Urban Forest Guidelines to assist Landscape Architects, City Planners, and designers to specify the types of trees to be planted in order to create a more beautiful and unified City. Homeowners can also benefit as they will be able to use these guidelines as a reference to make informed choices when planting trees.

Trees add scale and comfort to streets and their colors, shapes, and textures enhance the atmosphere and the identity of the City. The City's trees can be thought of as an "urban forest", and can be a diverse mixture of tree species. There are many growth characteristics and tree forms in street trees, and attention needs to be made to the trees you choose for your project. Street trees will grow for many years, and they must be properly placed and intelligently managed to maximize effects and minimize problems.

HOW TO USE THIS DOCUMENT

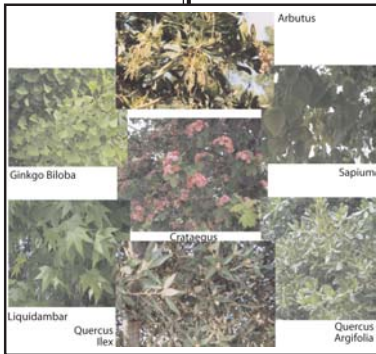
- Completely review the information in this document prior to deciding on street trees.
- Review and use the "Maintaining Street Trees" section in Appendix D for your planting and maintenance questions.
- Review the "Plans and Sections A - E" in Appendix A for the street type your project is located on, and use these to develop your street tree planting plan.
- Look over the "Street Tree List" spreadsheet in Appendix B and find a street tree that correlates with your street type and size of planting space. Note that other trees may be allowed, but it is up to the discretion of the Parks and Recreation Department. Check the characteristics listed on the top of the "Street Tree List" spreadsheet, and decide what criteria is important to you and could work well with your site.
- Look through the "Street Tree Photographs" in Appendix B and determine your favorite trees based on the aesthetics of the tree and the spreadsheet characteristics. For additional information and photos of the trees, go to <http://selectree.cagr.calpoly.edu/>. This website contains a lot of useful information on many trees and shrubs.

HOW TO PLAN FOR STREET TREE PLANTING

- Determine the type of street your property is located on (such as arterial or collector). See Appendix A for plans and sections of the different streets in Brentwood, and ask the Community Development Department if you are unsure.
- Find the correlating street development layout plans from the Engineering Department and design your project accordingly.
- Review the Landscaping and Plant Materials sections from the City of Brentwood's Plan Check Guidelines for additional information.
- Do a site analysis of your property - locate the direction of the wind and sun, the slopes and depressions, and views into and off the site. Also check for existing vegetation and any special considerations, such as utilities or signage.



- Prepare a preliminary street tree planting plan with a couple possible tree selections showing tree placement and spacing variations.
- Finalize your plans and tree choices, and review them with the City’s Parks and Recreation Department.
- Prepare a preliminary maintenance and watering plan, and review it with the City’s Parks and Recreation Department.



The combination of foliage and flowers generates visual interest through a variety of textures

STREET TREE CHARACTERISTICS AND CRITERIA

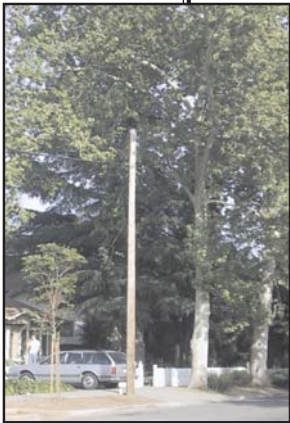
1. Street Tree Species and Spacing

Multiple Species

Mixed species result in better long-term management because they are less prone to diseases and insects than single species would be, and not all the trees will be lost if a disease or infestation should occur. The cohesive street plantings will help to harmonize the neighborhood and create visual unity. For each block on a street, no more than three species are recommended.

Many street tree combinations are possible, a few examples are:

- *Large shade trees mixed with flowering trees to create accents*
- *Evergreen trees mixed with deciduous trees to vary seasonal shade*
- *Different sizes or shapes of trees to mix up the silhouette of the street*
- *Fast and slow growing trees to create a variety of growth and losses*
- *Species with varieties of leaf colors and textures to generate visual interest*



A mixture of tree ages allows for a variation of growth and losses

Single Species

If a street already has many different tree species, a single type of tree is recommended to unify the diverse plantings. Should a single species be selected, it should be a large or medium size tree to provide a strong, unifying effect.

Attempt to match the most prevalent or most impressive existing tree species. Try to mimic the color and/or form of existing surrounding trees and repeat it throughout your project.



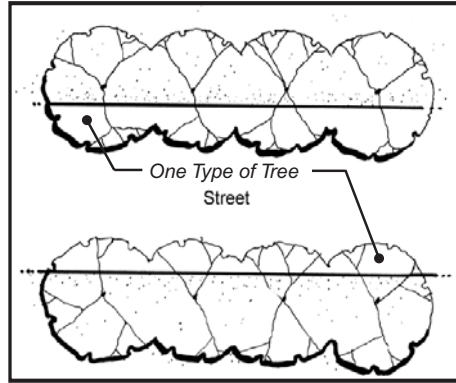
A single species of street tree can unify a street



Planting Patterns

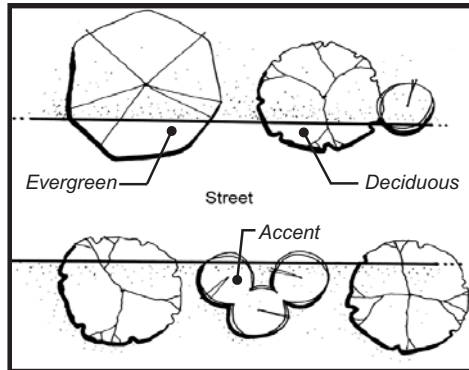
The tree species can be placed in various patterns, and below are examples of three typical situations - Regular, Irregular and Accent Spacing. See the Placement of Street Trees section in Chapter 4 for information on street tree spacing.

Regular Pattern - Repetitive pattern and spacing in tree locations. An example would be a formal and predetermined pattern of trees.



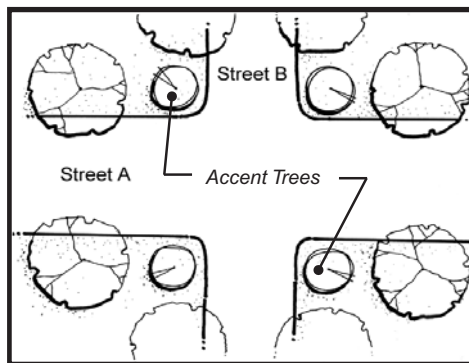
Typically use with monolithic or detached street spacing.

Irregular Pattern - Random spacing with no regular pattern. An example would be a natural and sporadic placement of a few types of trees. Species should still be limited to three selections in order to keep a uniform appearance.



Usually used with meandering street spacing.

Accent Pattern - Placing accent trees in specific locations. An example would be placing flowering trees at intersections or entries.



Generally use with any street spacing where accent is desired.



2. Street Tree Sizes

Selection of tree height and width is dependant on the type of street the project is located on. The main factors that determine the tree species on each street type are the growth rate, planting area constraints, and maintenance concerns.

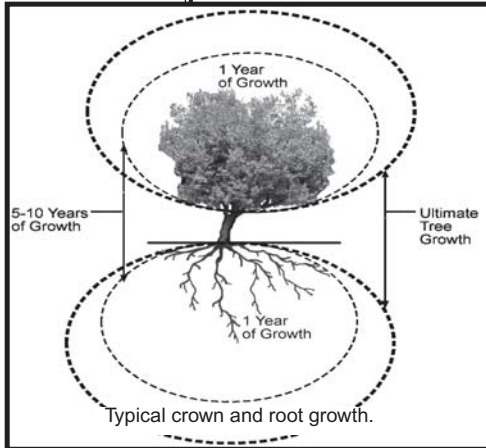


Illustration of approximate growth rate for a typical tree. In general, tree roots grow as large as the canopy.

Growth Rate

Fast growing species can quickly improve the visual effect, but they tend to be short-lived and will need to be replaced sooner. Slower growing species take longer to get the ultimate desired height, but they are much longer lived. It is recommended to combine both types of growth rates, and place the faster growing trees where the height is most needed. If you want quick coverage, consider the use of tall growing shrubs which can be cut back as the trees mature.

Existing trees should be protected and preserved if possible, and designated heritage trees may not be removed without prior City approval. Heritage trees are established trees with a historical significance, and/or exceptional horticultural interest.



Do not plant too close to powerlines. Trees could eventually grow into them.

The mixture of existing and new trees will balance the visual identity of the streets, and reduce the amount of trees to be removed in the future. The ideal street tree environment has a variety of tree species and growth rates that are repeated to give a sense of continuity and integrity to the City as a whole.

Planting Area Constraints

Additional site conditions will vary per project, but some constraints might include slopes, utilities, and existing vegetation. Maintain appropriate clearance from existing and proposed light fixtures, signs, soundwalls, fences, vegetation, and above and underground utilities. Consider the ultimate height and width that a tree will grow, and make sure to have the necessary clearance.

Do not plant within a minimum of 5 feet of hardscaping or underground utilities, and check with the local utility departments for specifications about your particular project. Also, trees should be planted 50 feet from any traffic sign or street light. (See Plans and Sections A-E in Appendix B for additional information.)

When planting new trees, it should be noted that Brentwood soils are highly alkaline and tree varieties should be chosen that are compatible with this condition. See Street Tree List (Soils and Maintenance Concerns notes) in Appendix B for more information. It is recommended that a soil sample testing be performed at all locations, and necessary soil amendment procedures should be followed.



If planting areas are restricted, use an engineered soil as specified by the City of Brentwood. Engineered soils can be used to encourage deep root growth and minimize conflicts with hardscaping. See Appendix E (Structural Soil Specifications) for additional information.

In general, roots extend approximately as far as the canopy width. With time, a tree can outgrow a space that is too small, and cause severe root damage to sidewalks and roadways. In areas located within 5 feet of hardscaping or underground utility lines, root deflection panels should be installed, deep rooting tree species should be used, and watering shall be applied to enhance deep rooting. Root barrier boxes and circling are not approved.

Maintenance Concerns

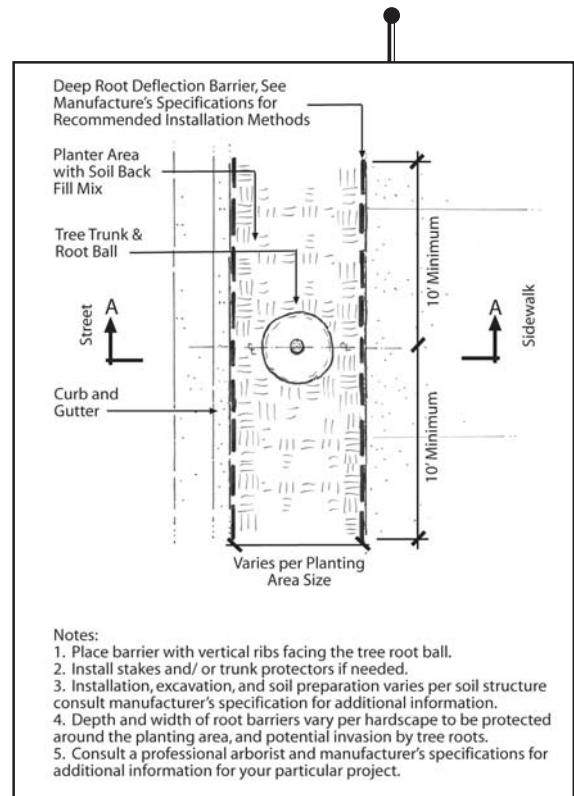
All street trees require maintenance and care, some more than others. Many trees produce leaf, flower and fruit drop; and most trees have periodic limb breakage. Consider the type of maintenance your street trees will be given when choosing the tree species. Place high maintenance trees in areas where they will be accessible, and ensure that high traffic areas are kept free of litter drop from the trees. See the “Maintaining Street Trees” section in Appendix D for additional information.



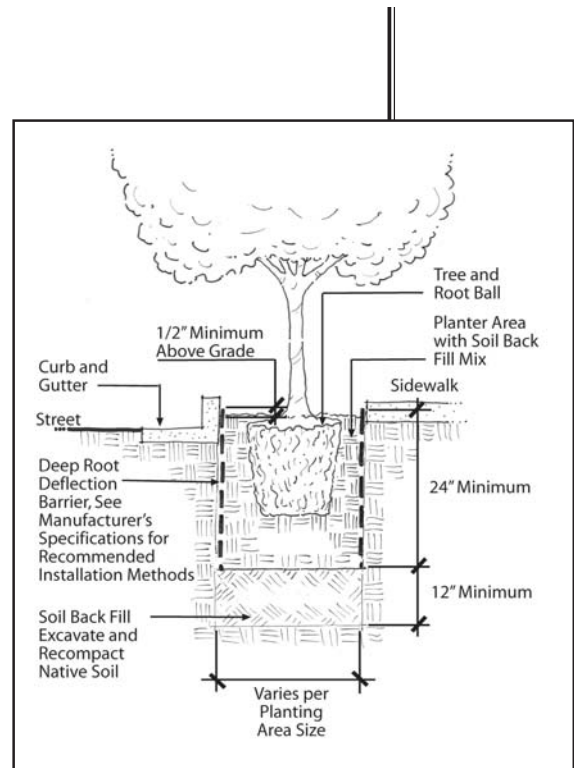
This sycamore tree has outgrown its planter and is damaging the sidewalk and curb.



Severely damaged sidewalks such as this can be hazardous to pedestrians and costly to repair.



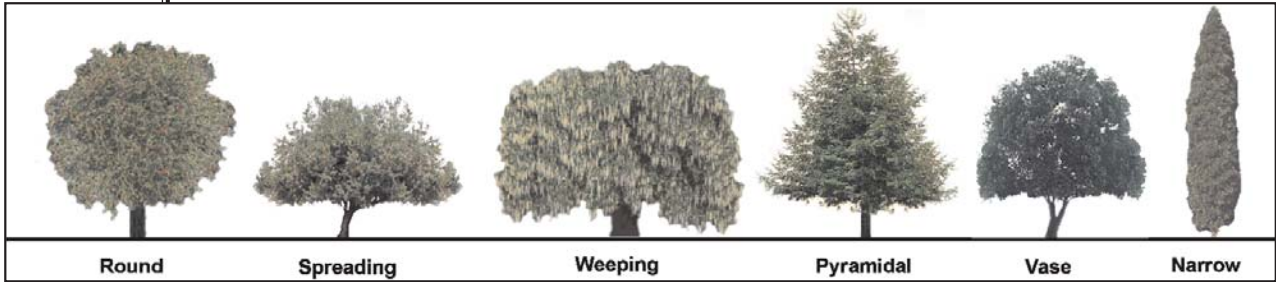
Plan view of typical root barrier installation. Place barriers parallel to elements needing protection.



Section view of typical root barrier placement

3. Street Tree Shape and Form

There are a variety of tree shapes, and the use of the desired forms can create different effects. When choosing a tree species consider the type of canopy shape and the street character you would like to create.



Tunnel Effect

A canopy of trees over a street can make a street feel more rural in character and human in scale. A tunnel effect can be very attractive and helps to unify a street. Canopies also create an informal atmosphere and a continuous pattern of shade on the street. A variety of tree shapes and species combinations helps to create the tunnel effect.

Corridor Effect

Tall, narrow trees planted in a row can create a corridor effect on a street. The corridor effect leads the eye and creates a very formal feeling to the neighborhood. The corridor effect does not usually cast as much shade on the street as the canopy effect does. The corridor effect is generally created with a narrow tree form and single tree species.

Low Branching Effect

Trees that are weeping and pyramidal in form tend to have low branches that could be a nuisance to pedestrians, bikes and cars. These trees can be beneficial in locations where low screening is desired. Combining shrubs underneath the street trees can also create a low branching effect and add to the screening.



Tunnel Effect



Corridor Effect



Low Branching Effect



4. Placement of Street Trees

Monolithic Street Spacing

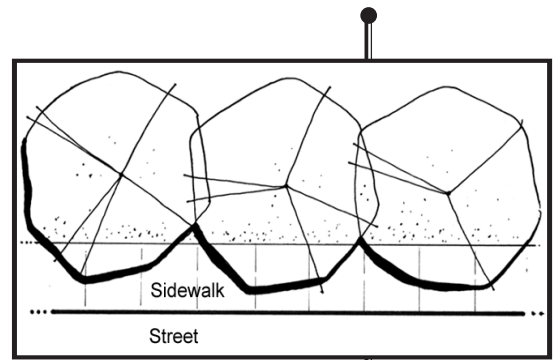
This type of spacing involves trees that are planted immediately adjacent to a sidewalk or bikeway in a regular pattern, and are the main identity of the street. These are generally medium to large trees, and this spacing can be used to provide a corridor or tunnel effect.

This type of spacing occurs on the following streets:

- *Industrial*
- *Medians*
- *Residential Collector*
- *Residential Local*



Monolithic Street Spacing



Monolithic Street Spacing can be used to create a corridor or tunnel effect.

Detached Street Spacing

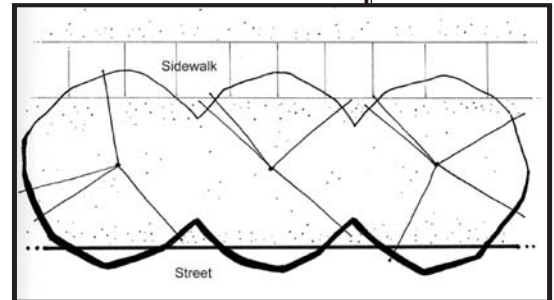
This spacing occurs when trees are planted between a sidewalk and the roadway or bikeway, and typically has a variety of patterns. This type of spacing is a useful method of separating the pedestrians from traffic areas. The trees for this spacing tend to be medium to large, and spreading in size in order to provide shade for both the sidewalk and the street area.

This type of spacing is encouraged in other areas if site conditions provide enough space, but the streets it occurs on are:

- *Arterial*
- *Collector*
- *Commercial*
- *Residential Collector*
- *Residential Local*



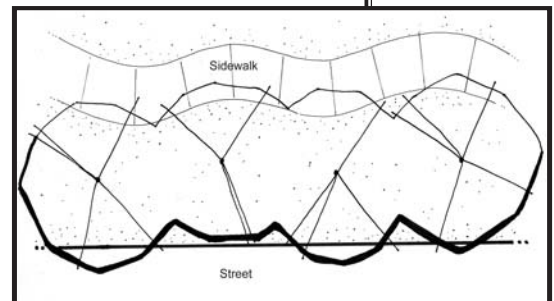
Detached Street Spacing



Detached Street Spacing is an effective way to removing pedestrians from traffic areas.

Meandering Street Spacing

This type of spacing usually involves a curvilinear walkway and ample planting area, and is generally used between a sidewalk and the street. This spacing can be used with any size tree, and looks more natural with a variety of sizes. The spacing is used with an irregular or accent pattern and it is typically triangulated and clustered in drifts, and tends to look like the trees are naturally occurring.



Meandering Street Spacing can give a street a natural look.

This type of spacing is recommended in other areas if site conditions allow, but the streets it occurs on are:

- Arterial
- Collector
- Industrial
- Residential Collector
- Residential Local
- Medians
- Cul-de-sac



Meandering Street Spacing



This *Pistacia chinensis* (Chinese Pistache) provides beautiful foliage in the fall and winter.

5. Foliage and Flowers

Seasonal Change

Evergreen trees provide year round screening and foliage. Deciduous trees lose their leaves in the winter, but provide fall color and interesting branching patterns. Leaf drop can become a problem in areas where maintenance will be minimal, and in these instances an evergreen would be a more appropriate selection.

Energy conservation can be affected by the type of tree selected. Proper placement of an evergreen tree can keep a building cool in the summer. A deciduous tree would do the same job in the summer, but also let the sun in and help to heat a building in the winter. Consider the ultimate height of a street tree, and the length of the shadows it will cast in its stages of growth.



Lagerströmia indica (Crape Myrtle) flowers add color and accent to this street.

Accent Trees

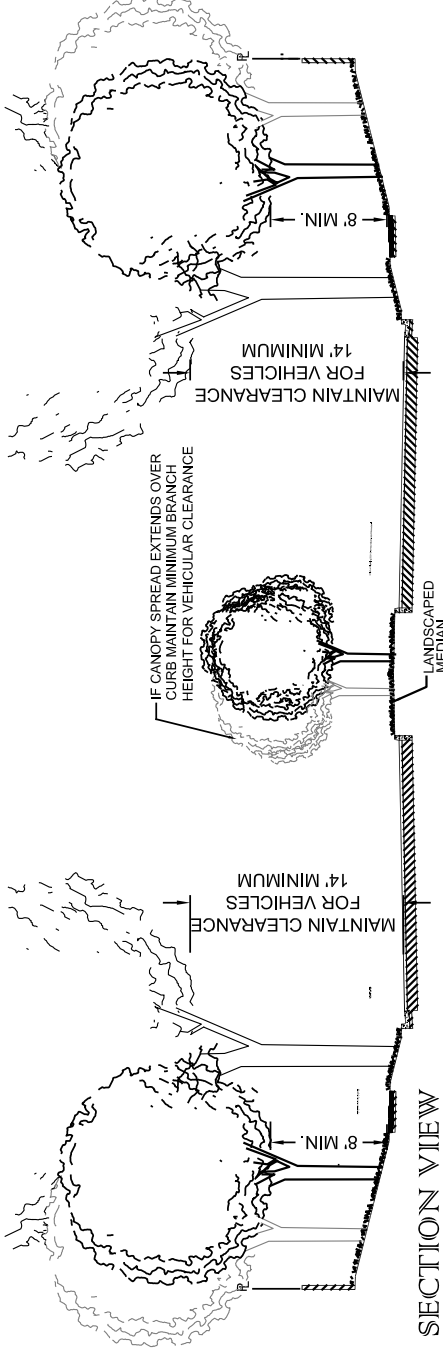
Flowering trees can be very useful for accent plantings, such as at entries and corners. It is recommended to combine accent or flowering trees with larger evergreen trees. The evergreen species can provide a strong background against the flowering branches of a deciduous tree. Accents can also be created by the use of combining or contrasting leaf textures and colors. Oftentimes, trees which flower also produce fruit and leaf drop, which can be a problem near parking areas and pedestrian walkways; and should, therefore, be carefully placed.



APPENDIX A:

Plans and Sections for Street Types

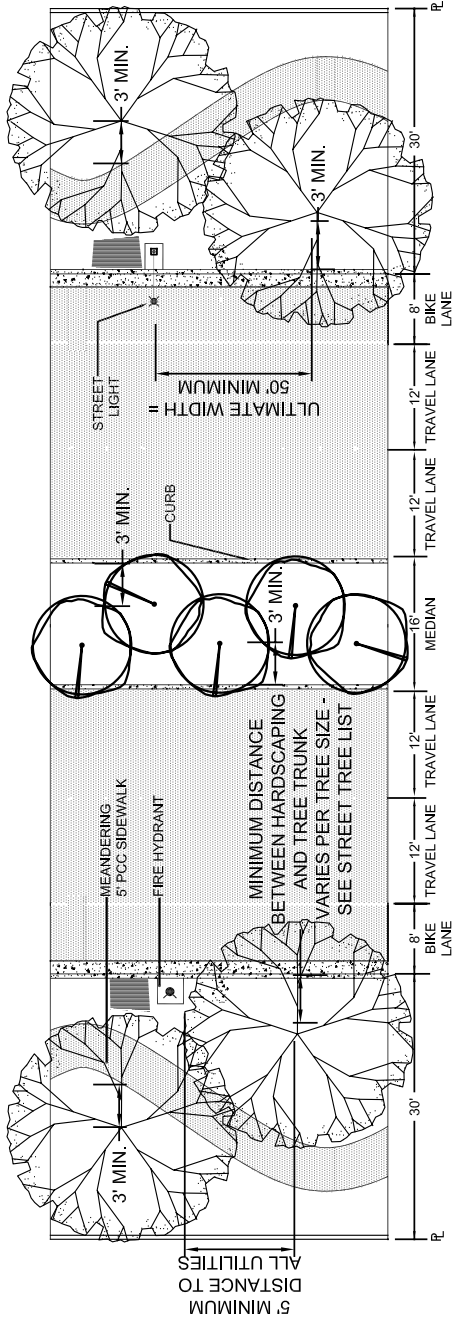




SECTION VIEW

Not To Scale

NOTE: ALL PLANTING AREAS THAT ARE LESS THAN 10' WIDE REQUIRE ROOT DEFLECTION BARRIERS, SEE PAGE 5 OF THIS DOCUMENT FOR MORE INFORMATION.



PLAN VIEW

Not To Scale

Arterial Street Tree Characteristics

Tree Size - Medium to Large
 Growth Rate - Moderate to Fast
 Evergreen or Deciduous - Either, See Accent Planting Below
 Water Usage - Moderate to Regular
 Maintenance Concerns - Fruit and Leaf Drop, Invasive Roots
 Where Hardscape Exists - May Need Deep Root Barriers,
 Deep Watering, and Regular Raking and Sweeping
 Accent Planting - Flowers, Fruits & Berries, and Fall Color
 Canopy Shape - Any
 Screening - If Undesirable Views Exist
 Spacing - Meandering, Naturalize in Groups, Cluster in Drifts
 Hardscape Concerns - Bike Lane and Traffic Areas
 (Minimum 14') Sidewalk (8' Minimum), Street Lights
 (Minimum 50'), Fire Hydrant (5' Minimum),
 Street Signs (Minimum 50')
 Comments - Conditions Dictate Planting Locations, and
 Spacing Based on Tree Selection

Median Street Tree Characteristics

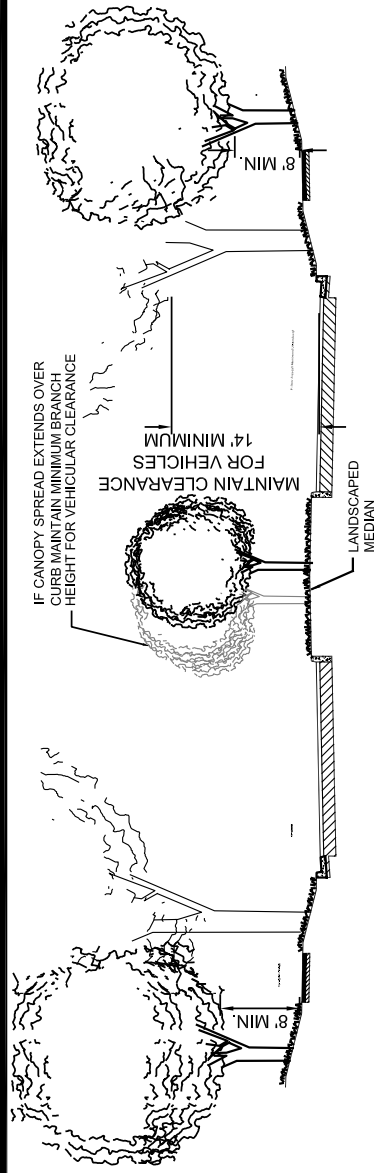
Tree Size - Small to Medium
 Growth Rate - Slow to Moderate
 Evergreen or Deciduous - Either, See Accent Planting Below
 Water Usage - Regular to Ample
 Maintenance Concerns - Fruit and Leaf Drop, Invasive Roots
 Where Hardscape Exists - May Need Deep Root Barriers,
 Deep Watering, and Regular Raking and Sweeping
 Accent Planting - Flowers, Fruits & Berries and Fall Color
 Canopy Shape - Any
 Screening - If Undesirable Views Exist
 Spacing - Meandering in Groups, More Formal than Arterial
 Hardscape Concerns - Traffic Areas (Minimum 14')
 Comments - Conditions Dictate Planting Locations, and
 Spacing Based on Tree Selection

Collector Street Tree Characteristics

Tree Size - Medium to Large
 Growth Rate - Slow to Fast
 Evergreen or Deciduous - Either, See Accent Planting Below
 Water Usage - Low to Moderate
 Maintenance Concerns - Fruit and Leaf Drop, Invasive Roots
 Where Hardscape Exists - May Need Deep Root Barriers,
 Deep Watering, and Regular Raking and Sweeping
 Accent Planting - Flowers, Fruits & Berries and Fall Color
 Canopy Shape - Any
 Screening - If Undesirable Views Exist
 Spacing - Meandering, Naturalize in Groups, Cluster in Drifts
 Hardscape Concerns - Bike Lane and Traffic Areas
 (Minimum 14'), Sidewalk (8' Minimum), Street Lights
 (Minimum 50'), Fire Hydrant (5' Minimum),
 Street Signs (minimum 50')
 Comments - Conditions Dictate Planting Locations, and
 Spacing Based on Tree Selection

Median Street Tree Characteristics

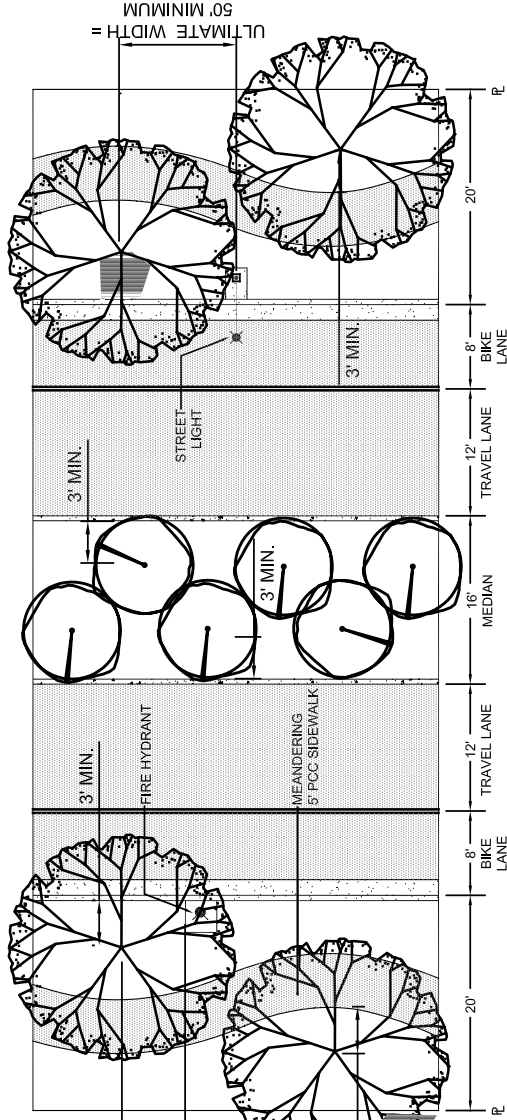
Tree Size - Small to Medium
 Growth Rate - Slow to Moderate
 Evergreen or Deciduous - Either, See Accent Planting Below
 Water Usage - Regular to Ample
 Maintenance Concerns - Fruit and Leaf Drop, Invasive Roots
 Where Hardscape Exists - May Need Deep Root Barriers,
 Deep Watering, and Regular Raking and Sweeping
 Accent Planting - Flowers, Fruits & Berries and Fall Color
 Canopy Shape - Any
 Screening - If Undesirable Views Exist
 Spacing - Meandering in Groups, More Formal than Arterial
 Hardscape Concerns - Traffic Areas (Minimum 14')
 Comments - Conditions Dictate Planting Locations, and
 Spacing Based on Tree Selection



SECTION VIEW

Not To Scale

NOTE: ALL PLANTING AREAS THAT ARE LESS THAN 10' WIDE REQUIRE ROOT DEFLECTION BARRIERS. SEE PAGE 5 OF THIS DOCUMENT FOR MORE INFORMATION.



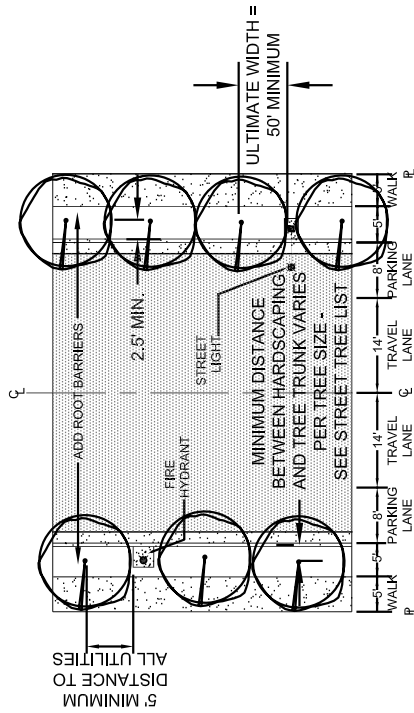
PLAN VIEW

Not To Scale

MINIMUM DISTANCE BETWEEN HARDSCAPING AND TREE TRUNK VARIES PER TREE SIZE - SEE STREET TREE LIST

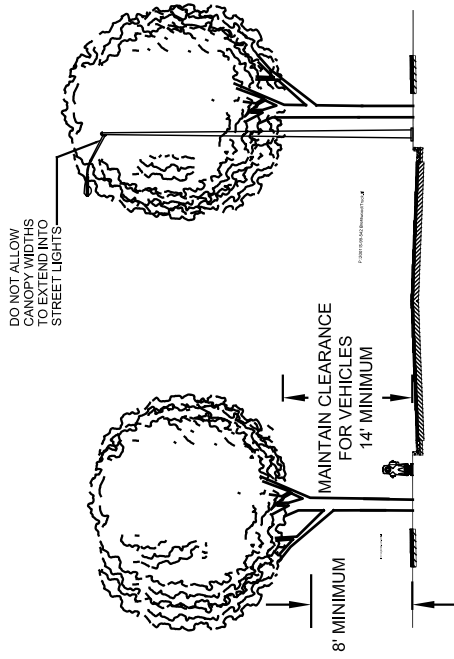
COLLECTOR STREET TREE PLANTING

NOTE: ALL PLANTING AREAS THAT ARE LESS THAN 10' WIDE REQUIRE ROOT DEFLECTION BARRIERS, SEE PAGE 5 OF THIS DOCUMENT FOR MORE INFORMATION.



PLAN VIEW

Not To Scale



SECTION VIEW

Not To Scale

Commercial Street Tree Characteristics

- Tree Size - Small to Medium
- Growth Rate - Moderate to Fast
- Evergreen or Deciduous - Either, See Accent Planting Below
- Water Usage - Low to Ample
- Maintenance Concerns - Fruit and Leaf Drop, Invasive Roots
- Where Hardscape Exists - May Need Deep Root Barriers, Deep Watering, and Regular Raking and Sweeping
- Accent Planting - Flowers, Fruits & Berries, and Fall Color
- Canopy Shape - Not Spreading or Pyramidal, Unless Room Screening - If Undesirable Views Exist
- Spacing - Detached, Formal, Linear and Consistent, but Leave Openings for Signs and Entries
- Hardscape Concerns - Parking Lane and Traffic Areas (Minimum 14'), Sidewalk (8' Minimum), Street Lights (Minimum 50'), Fire Hydrant (5' Minimum), Street Signs (Minimum 50')
- Comments - Conditions Dictate Planting Locations, and Spacing Based on Tree Selection

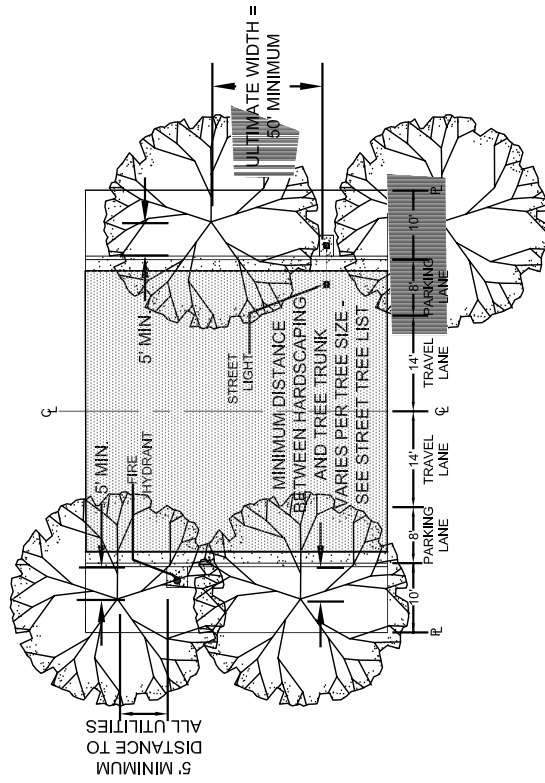
©2007 ES&S Environmental Services

COMMERCIAL STREET TREE PLANTING

PLAN C
COMMERCIAL STREET

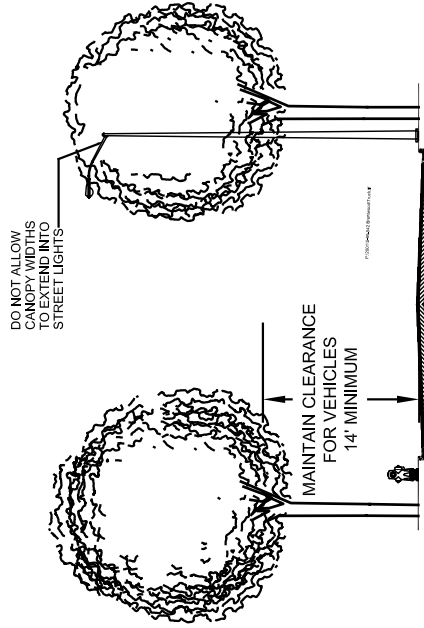
P:\2007\IS-99-542 Brentwood\Plans&Rec_LoggsB,K_VHT.dwg

NOTE: ALL PLANTING AREAS THAT ARE LESS THAN 10' WIDE REQUIRE ROOT DEFLECTION BARRIERS. SEE PAGE 5 OF THIS DOCUMENT FOR MORE INFORMATION.



PLAN VIEW

Not To Scale



SECTION VIEW

Not To Scale

Industrial Street Tree Characteristics

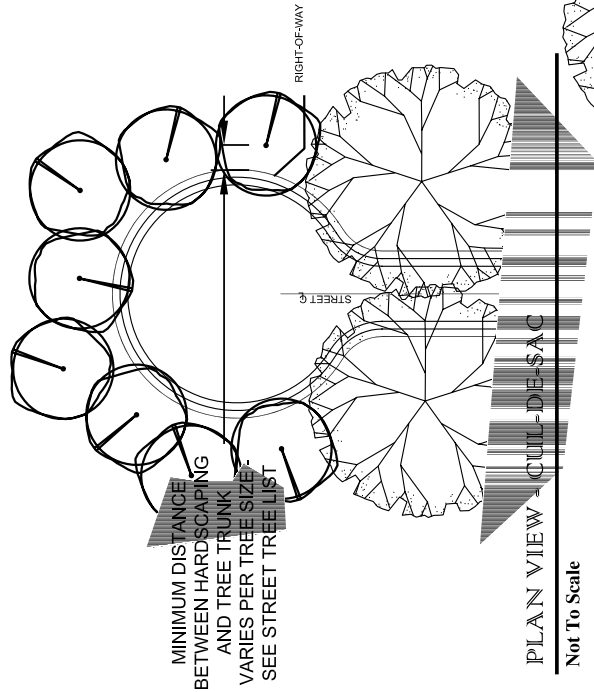
- Tree Size - Medium to Large
- Growth Rate - Slow to Fast
- Evergreen or Deciduous - Either, See Accent Planting Below
- Water Usage - Low to Ample
- Maintenance Concerns - Fruit and Leaf Drop, Invasive Roots
- Where Hardscape Exists - May Need Deep Root Barriers, Deep Watering, and Regular Raking and Sweeping
- Accent Planting - Flowers, Fruits & Berries and Fall Color
- Canopy Shape - Any, Prefer Dense and Compact Canopies
- Screening - If Undesirable Views Exist, May Need Shrubs
- Spacing - Monolithic or Meandering, Tight & Consistent, but Leave Openings for Signs and Entries
- Hardscape Concerns - Parking Lane and Traffic Areas (Minimum 14'), Street Lights (Minimum 50'), Fire Hydrant (Minimum 5'), Street Signs (Minimum 50')
- Comments - Conditions Dictate Planting Locations, and Spacing Based on Tree Selection

Cul-De-Sac Street Tree Characteristics

Tree Size - Small to Medium
 Growth Rate - Slow to Moderate
 Evergreen or Deciduous - Either, See Accent Planting Below
 Water Usage - Regular to Ample
 Maintenance Concerns - Fruit and Leaf Drop, Invasive Roots
 Where Hardscape Exists - May Need Deep Root Barriers,
 Deep Watering, and Regular Raking and Sweeping
 Accent Planting - Flowers, Fruits & Berries, and Fall Color
 Canopy Shape - Any
 Screening - If Undesirable Views Exist
 Spacing - Meandering, Tight and Consistent Spacing, but
 Leave Openings for Entries
 Hardscape Concerns - Parking Lane and Traffic Areas
 (Minimum 14'), Sidewalks (8' Minimum), Street Lights
 (Minimum 50'), Fire Hydrant (Minimum 5'),
 Street Signs (Minimum 50')
 Comments - Conditions Dictate Planting Locations, and
 Spacing Based on Tree Selection

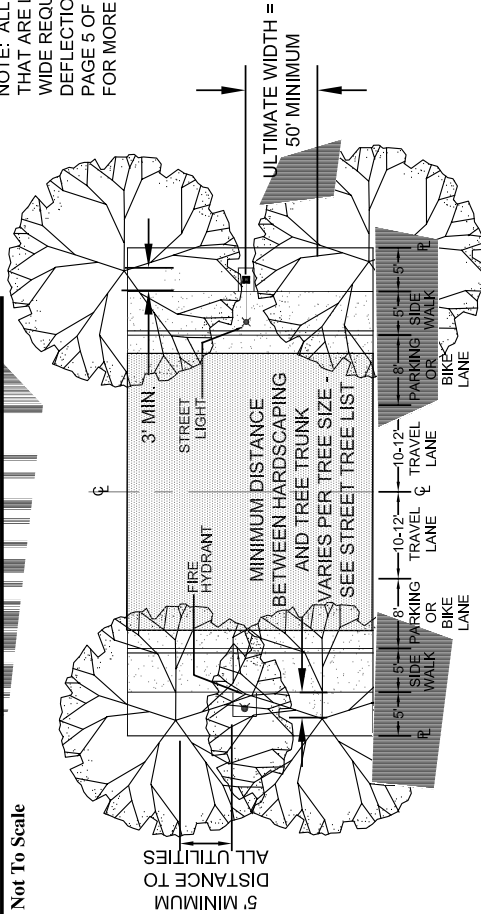
Local and Residential Collector Street Tree Characteristics

Tree Size - Medium to Large
 Growth Rate - Moderate to Fast
 Evergreen or Deciduous - Either, See Accent Planting Below
 Water Usage - Low to Ample
 Maintenance Concerns - Fruit and Leaf Drop, Invasive Roots
 Where Hardscape Exists - May Need Deep Root Barriers,
 Deep Watering, and Regular Raking and Sweeping
 Accent Planting - Flowers, Fruits & Berries, and Fall Color
 Canopy Shape - Any, Prefer High Branching and Spreading
 Screening - If Undesirable Views Exist, May Need Additional Shrubs
 Spacing - Monolithic, Formal, Linear and Consistent, but Leave
 Openings for Signs and Entries
 Hardscape Concerns - Parking Lane and Traffic Areas
 (Minimum 14'), Sidewalks (8' Minimum), Street Lights
 (Minimum 50'), Fire Hydrant (Minimum 5'),
 Street Signs (Minimum 50')
 Comments - Conditions Dictate Planting Locations, and
 Spacing Based on Tree Selection

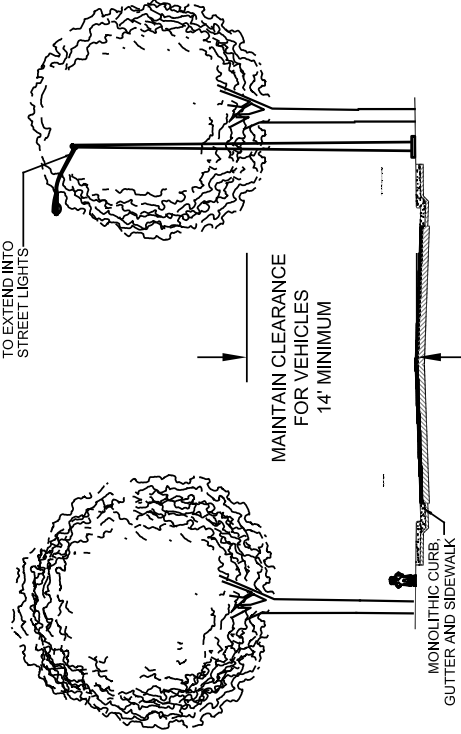


PLAN VIEW - CUL-DE-SAC
 Not To Scale

NOTE: ALL PLANTING AREAS THAT ARE LESS THAN 10' WIDE REQUIRE ROOT DEFLECTION BARRIERS. SEE PAGE 5 OF THIS DOCUMENT FOR MORE INFORMATION.



PLAN VIEW - LOCAL, RESIDENTIAL COLLECTOR
 Not To Scale



SECTION VIEW - LOCAL, RESIDENTIAL COLLECTOR
 Not To Scale


LOCAL, RESIDENTIAL COLLECTOR STREET TREE PLANTING

PLAN E
LOCAL STREET, RESIDENTIAL COLLECTOR, AND CUL-DE-SAC

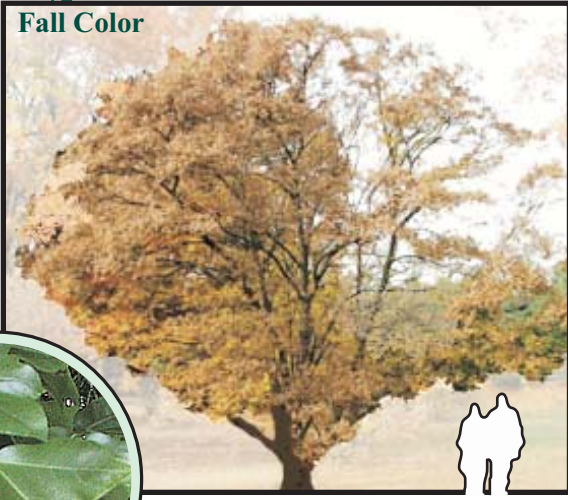
APPENDIX B

Street Tree List and Photographs



TREE NAME	Botanical Name	Acer buergeranum	Acer campestre 'Queen Elizabeth'	Arbutus 'Marina'	Arbutus menziesii
	Common Name	Trident Maple	Queen Elizabeth Hedge Maple	Hybrid Strawberry Tree	Madrone
STREET TYPE	Medians & Cul-de-Sacs (A&E)				
	Residential & Local (E)				
	Industrial (D)				
	Commercial (C)				
	Collector (B)				
	Arterial (A)				
	Plant Photo Number (See Following Page)	1	2	3	4
Tree Size	Small	Medium	Medium	Medium	
Growth Rate	Slow	Slow	Slow to Moderate	Slow to Moderate	
Planter Size	Minimum 6'	Minimum 10'	Minimum 10'	Minimum 10'	
Evergreen	No	No	Yes	Yes	
Canopy Shape	Spreading	Round	Round	Round	
Leaf Color and Texture	Dark green top, pale below, glossy	Dull green, Glossy	Dark green with red stems	Dark green top, dull grey green below, shiny	
Leaf Size & Shape	3", Lobed	2-4", Lobed	3-4", Oblong	3-6"	
Fall Color	Red, Then Varies to Yellow or Orange	Yellow	None	None	
Fruits/ Berries/ Nuts	Medium, Brown or Yellow Winged Seeds (Summer)	Inconspicuous	Small, Red or Yellow (Fall to Winter)	Red and Orange (Fall)	
Flowering	Yellow (Spring)	Inconspicuous	Rosy Pink (Fall)	White to Pink (Spring)	
Water	Moderate to Ample, Regular and Deep	Regular, Ample, Deep	Any	Low, water to establish then infrequent & deep. Use nonalkaline water.	
Soil	Any Soil, Tolerates Alkalinity	Any, Well-Drained, Tolerates Alkalinity	Any, Tolerates Slightly Alkaline	Needs Acidic to Neutral, Fast Drainage, Clay to Loam	
Sun	Full Sun to Part Shade	Full Sun to Part Shade	Full Sun to Part Shade	Sun or Shade	
Maintenance Concerns	Leaf & Dry Fruit Drop, Needs Staking & Pruning, Roots Slightly Invasive	Needs Staking and Pruning, Roots Slightly Invasive	Wet Fruit Drop	Wet Fruit Drop	
Comments	Dense and compact form, Resistant to many pests and diseases.	Dense and compact form	Basal suckers & stem sprouts, prune (not shear) to create open-crown. Fruit drop not suitable along sidewalks or streets.	Bark smooth, reddish brown & peels, horizontally tiered branches & broad form. Fruit drop not suitable along sidewalks or streets.	

Fall Color



1. *Acer buergerianum*
Trident Maple
(25' high x 25' wide)



3. *Arbutus 'Marina'*
Hybrid Strawberry Tree
(40' high x 40' wide)



2. *Acer campestre*
Queen Elizabeth Hedge Maple
(30-70' h x 30-70' w)



4. *Arbutus menziesii*
Madrone
(30-70' h x 30-70' w)



Street Tree Photographs



City of Brentwood
Parks and Recreation Department

TREE NAME	Botanical Name	Betula platyphylla 'Whitespire'	Carpinus betulus 'fastigiata'	Celtis australis	Celtis sinensis
	Common Name	Whitespire Japanese Birch	Fastigate Hornbeam	European Hackberry	Chinese Hackberry
STREET TYPE	Medians & Cul-de-Sacs (A&E)				
	Residential & Local (E)				
	Industrial (D)				
	Commercial (C)				
	Collector (B)				
	Arterial (A)				
	Plant Photo Number (See Following Page)	5	6	7	8
	Tree Size	Medium	Medium	Medium to Large	Medium to Large
Growth Rate	Fast	Moderate	Moderate	Slow to Moderate	
Planter Size	Minimum 15'	Minimum 10'	Minimum 15'	Minimum 15'	
Evergreen	No	No	No	No	
Canopy Shape	Narrow	Vase (Youth)/ Weeping	Round, Narrow	Round, Narrow	
Leaf Color and Texture	Green, Glossy	Dark Green	Dark Green	Bright Green, Smooth & Glossy	
Leaf Size & Shape	3", Fine Toothed	2-5", Toothed	2-5", Coarsely Toothed	4", Scalloped Tooth	
Fall Color	Yellow	Yellow or Dark Red	Gold	Gold	
Fruits/ Berries/ Nuts	Catkin Clusters, Brown (Summer to Winter)	Brown Fruit, 5" Long, Winged Seed	Small, Black or Purple (Summer and Fall)	Small, Orange or Purple (Summer and Fall)	
Flowering	Inconspicuous	Inconspicuous	Inconspicuous	Inconspicuous	
Water	Regular, Ample	Low to Regular	Drought Tolerant	Drought Tolerant	
Soil	Any, Tolerates Alkalinity	Needs Acidic, Clay to Loam	Any but avoid clay, Tolerates Alkalinity	Any but avoid clay, Tolerates Alkalinity	
Sun	Full Sun to Part Shade	Full Sun to Part Shade	Sun or Shade	Sun or Shade	
Maintenance Concerns	Moderate Root Damage and Insect Potential, Dry Fruit Drop	Dry Fruit Drop	Moderate Root Damage & Insect Potential, Needs Staking & Pruning, Dry Fruit Drop	Moderate Root Damage & Insect Potential, Needs Staking & Pruning, Dry Fruit Drop	
Comments	Susceptable to aphids that drip honeydew, Needs regular fertilizing, Open form in maturity	Retains leaves into winter, Subject to scale insects. Fruit drop not suitable along sidewalks or streets.	Deep surface roots, good for windy locations, attractive to birds, occasional aphid attacks	Deep surface roots, good for windy locations, attractive to birds, occasional aphid attacks. Good choice for tree wells.	



5. *Betula platyphylla*
Japanese Birch
(40' high x 30' wide)



7. *Celtis australis*
European Hackberry
(40' high x 40' wide)



6. *Carpinus betulus*
European Hornbeam
(40' high x 30' wide)



8. *Celtis sinensis*
Chinese Hackberry
(35' high x 35' wide)

Street Tree Photographs

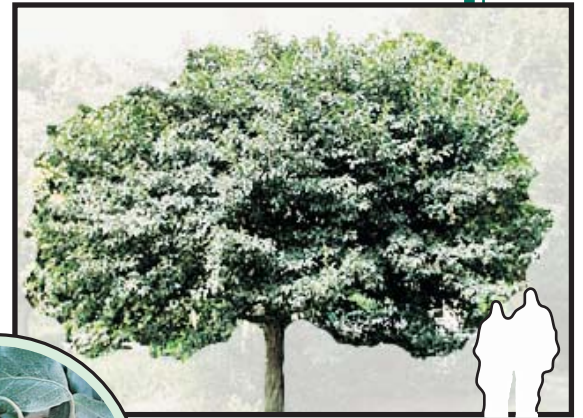


TREE NAME	Botanical Name	<i>Cercis canadensis</i>	<i>Cercis reniformis</i> 'Oklahoma'	<i>Chionanthus retusus</i>	<i>Cladrastis lutea</i>
	Common Name	Eastren Redbud	Oklahoma Redbud	Chinese Fringe Tree	Yellow Wood
STREET TYPE	Medians & Cul-de-Sacs (A&E)				
	Residential & Local (E)				
	Industrial (D)				
	Commercial (C)				
	Collector (B)				
	Arterial (A)				
	Plant Photo Number (See Following Page)	9	10	11	12
Tree Size	Small to Medium	Small to Medium	Small	Small to Medium	
Growth Rate	Moderate to Fast	Fast	Slow to Moderate	Slow	
Planter Size	Minimum 8'	Minimum 8'	Minimum 6'	Minimum 8'	
Evergreen	No	No	No	No	
Canopy Shape	Round	Round	Round	Round	
Leaf Color and Texture	Rich Green	Blue Green, Leathery	Green	Bright Green	
Leaf Size & Shape	3-6", Round, Pointed & Heart Base	2-3", Notched Tip & Heart Base	Broad, Oval	8-12", Divided	
Fall Color	Yellow, Orange or Red	Yellow, Orange or Red	Deep Yellow	Deep Yellow	
Fruits/ Berries/ Nuts	Large Green, Brown or Purple Pods (Summer)	Purple, Persistant	If male & female, resembles small dark olives	Large Brown Pods (Summer to Fall)	
Flowering	Rosy Pink (Early Spring)	White to Pink (Early Spring)	White (June & July)	White, Fragrant - After Mature (May or Early June)	
Water	Regular to Moderate	Low to Regular	Moderate to Ample	Moderate to Ample	
Soil	Any, Tolerates Alkalinity	Well-Drained, Tolerates Alkalinity	Well-Drained, Tolerates Slightly Alkaline	Well-Drained & Acidic, Clay, Loam or Sand	
Sun	Full Sun to Part Shade	Full Sun to Part Shade	Full Sun to Part Shade	Full Sun to Part Shade	
Maintenance Concerns	Dry Fruit Drop, Resistant to most pests and diseases	None	Wet Fruit Drop	Dry Fruit Drop, Needs Staking and Pruning (When Young)	
Comments	Easily takes tree form, horizontally tiered branches create broad form in maturity	Horizontally tiered branches create broad form in maturity	Low growing, and in maturity displays horizontally tiered branches creating a broad form. Do not plant females close to pavement (Fruit drop)	Remove lower branches entirely to get height, horizontally tiered branches create broad form in maturity	

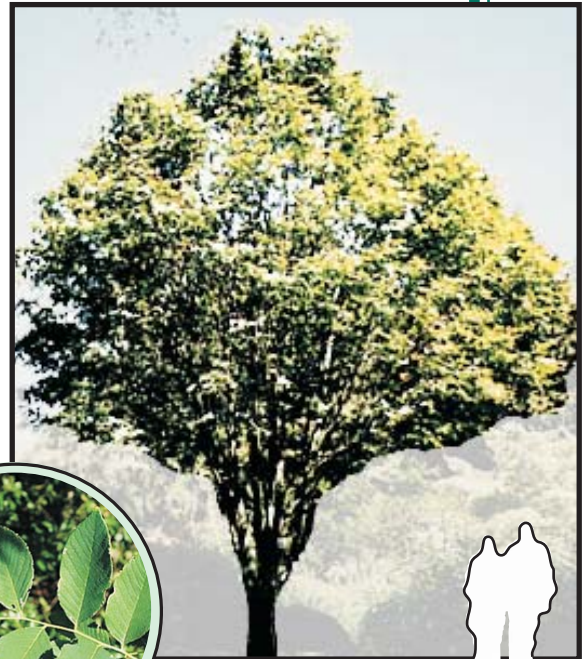
STREET TREE CHARACTERISTICS



9. *Cercis canadensis*
Eastren Redbud
(30' high x 30' wide)



11. *Chionanthus retusus*
Chinese Fringe Tree
(20' high x 20' wide)



12. *Cladrastis lutea*
Yellow Wood
(30' high x 20' wide)



10. *Cercis reniformis*
Redbud
(30' high x 30' wide)



Street Tree Photographs



TREE NAME	Botanical Name	Cornus capitata	Cornus kousa	Crataegus phaenopyrum	Geijera parviflora
	Common Name	Evergreen Dogwood	Kousa Dogwood	Washington Thorn	Australian Willow
STREET TYPE	Medians & Cul-de-Sacs (A&E)				
	Residential & Local (E)				
	Industrial (D)				
	Commercial (C)				
	Collector (B)				
	Arterial (A)				
	Plant Photo Number (See Following Page)	13	14	15	16
Tree Size	Small to Medium	Small	Small	Small to Medium	
Growth Rate	Moderate	Slow to Moderate	Moderate	Moderate to Fast	
Planter Size	Minimum 8'	Minimum 6'	Minimum 6'	Minimum 8'	
Evergreen	Yes (Semi-Evergreen below 15 Degrees)	No	Yes	Yes	
Canopy Shape	Round	Round	Round	Weeping	
Leaf Color and Texture	Green to Grayish Green	Medium Green with brown hairs, lustrous	Green, Glossy	Medium Green	
Leaf Size & Shape	2-4", Narrow	4"	2-3", Sharp Pointed Lobes	3-6", Narrow, Drooping	
Fall Color	Red to Purple	Yellow or Scarlet	Orange and Red	None	
Fruits/ Berries/ Nuts	Reddish-Purple Fruit (Oct to Nov)	Red Fruit (October)	Shiny Red (Autumn to Winter)	Inconspicuous	
Flowering	Creamy to Pale Yellow - After Mature (May to June)	White with Pink Edges (June to July)	White (Late Spring or Early Summer)	Inconspicuous	
Water	Ample	Ample	Any - Less water results in better growth	Any - Ample results in faster growth	
Soil	Well-Drained & Acidic, Clay, Loam or Sand	Well-Drained & Acidic, Clay, Loam or Sand	Tolerates Alkalinity	Well-Drained	
Sun	Full Sun to Part Shade	Full Sun to Part Shade	Full Sun	Full Sun to Part Shade	
Maintenance Concerns	Messy Fruit Drop	Messy Fruit and Leaf Drop	Disease and Insect Potential, Needs Staking and Pruning	Needs Staking and Pruning, Dry Fruit Drop	
Comments	Multi-Trunked, Fruit drop not suitable along sidewalks or streets.	Multi-Trunked, dense and compact form. Fruit drop not suitable along sidewalks or streets.	Thorny, needs pruning to thin, aphids and fireblight potential, attracts bees and birds, Open form. Fruit drop not suitable along sidewalks or streets.	Need pruning only to desired form, low maintenance and virtually pest free	



**13. *Cornus capitata*
Evergreen Dogwood
(25' high x 25' wide)**



**14. *Cornus kousa*
Kousa Dogwood
(25' high x 25' wide)**



**15. *Crataegus phaenopyrum*
Washington Thorn
(20' high x 20' wide)**






**16. *Geijera parviflora*
Australian Willow
(25' high x 20' wide)**



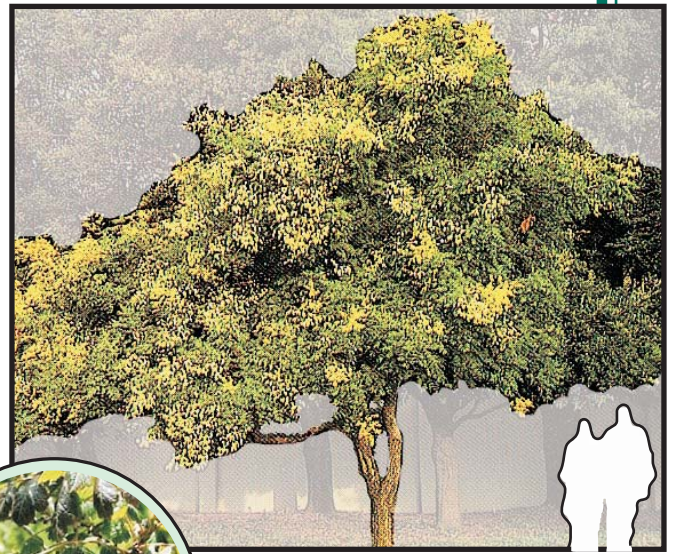
**Street Tree
Photographs**



TREE NAME	Botanical Name	Ginkgo biloba "Fairmount"	Koelreuteria bipinnata	Koelreuteria paniculata	Lagerstroemia indica
	Common Name	Maidenhair Tree	Chinese Flame Tree	Goldenrain Tree	Crape Myrtle
STREET TYPE	Medians & Cul-de-Sacs (A&E)				
	Residential & Local (E)				
	Industrial (D)				
	Commercial (C)				
	Collector (B)				
	Arterial (A)				
	Plant Photo Number (See Following Page)	17	18	19	20
Tree Size	Medium to Large	Small to Medium	Small to Medium	Small	
Growth Rate	Slow to Moderate	Slow to Moderate	Moderate	Slow to Moderate	
Planter Size	Minimum 17'	Minimum 8'	Minimum 8'	Minimum 6'	
Evergreen	No	No	No	Yes	
Canopy Shape	Spreading, Pyramidal,	Spreading	Spreading/ Open	Vase	
Leaf Color and Texture	Light Green, Leathery	Green	Green	Dark green, glossy	
Leaf Size & Shape	1-4", Fan Shaped , resemble Maidenhair Ferns	24-48", divided into many oval leaflets	15", with 7 to 15 toothed or lobed leaflets	1-2", oval	
Fall Color	Golden (Begins in Summer)	Bronze or Yellow for a Short Time	Bronze or Yellow for a Short Time	Yellow, Sometimes Orange to Red	
Fruits/ Berries/ Nuts	None	2", orange to red (Late Summer to Fall)	2", buff to brown (Fall)	Small Brown Capsules	
Flowering	Inconspicuous	Small Yellow (Summer)	Small Yellow (Summer)	Many varieties (July to September)	
Water	Water moderately until 20' high, then low	Moderate	Regular in youth, then tolerates drought	Drought-Tolerant, Infrequent, but deep	
Soil	Deep, Loose, Well-Drained	Well-Drained, Tolerates Alkalinity	Well-Drained, Tolerates Alkalinity	Acidic to Slightly Alkaline. Clay, Loam or Sand	
Sun	Full Sun to Part Shade	Full Sun to Part Shade	Full Sun to Part Shade	Full Sun	
Maintenance Concerns	Best with some Care. Moderate Root Damage & Leaf Drop, Needs Staking and Pruning	Needs Staking and Pruning	Needs Staking and Pruning, Roots May Be Invasive	Needs staking & pruning. Resistant to most pests & diseases, subject to aphids. Dry fruit drop.	
Comments	Gawky & brittle in youth, stake well, becomes proportioned with age. Plant male trees only, females have messy fruits.	Roots deep and not invasive, fruit not dependable, stake and prune to develop high branches. Fruit drop not suitable along sidewalks or streets.	Tolerates cold, heat, drought, wind, alkaline soil. Can be gawky without pruning. Fruit drop not suitable along sidewalks or streets.	Attractive trunk and branching pattern, prune when dormant to increase flowering, Needs moderate fertilizing. Indian varieties are mildew resistant	



17. Ginkgo biloba
Maiden Hair Tree
(50-80' h x 30-50' w)



19. Koelreuteria paniculata
Goldenrain Tree
(25' high x 20' wide)



18. Koelreuteria bipinnata
Chinese Flame Tree
(30' high x 30' wide)













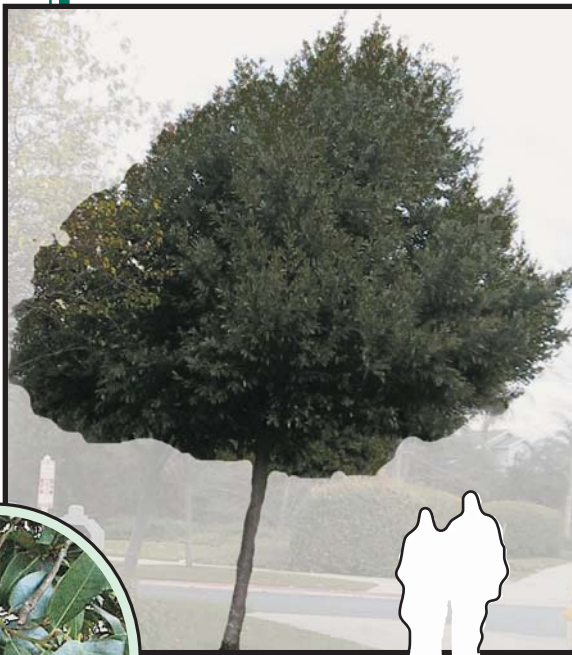
20. Lagerstroemia indica
Crape Myrtle
(20' high x 20' wide)



Street Tree Photographs



TREE NAME	Botanical Name	Laurus nobilis	Liquidambar styraciflua	Magnolia grandiflora	Pistacia chinensis
	Common Name	Sweet Bay	American Sweet Gum	Southern Magnolia	Chinese Pistache
STREET TYPE	Medians & Cul-de-Sacs (A&E)				
	Residential & Local (E)				
	Industrial (D)				
	Commercial (C)				
	Collector (B)				
	Arterial (A)				
	Plant Photo Number (See Following Page)	21	22	23	24
Tree Size	Small to Medium	Large	Large	Medium to Large	
Growth Rate	Slow	Moderate	Slow to Moderate	Moderate	
Planter Size	Minimum 12'	Minimum 25'	Minimum 25'	Minimum 15'	
Evergreen	Yes	No	Yes	No	
Canopy Shape	Vase	Narrow	Round	Round	
Leaf Color and Texture	Dark green, leathery	Deep Green	Dark Green, Glossy and leathery	Green	
Leaf Size & Shape	2-4", aromatic, oval	3-7", Lobed, Maple-Like	4-8"	2-4", Narrow, 10 - 16 paired leaflets	
Fall Color	None	Purple, Yellow or Red	None	Scarlet, Crimson, Orange or Yellow	
Fruits/ Berries/ Nuts	Black or dark purple berries	Hanging spiny balls (Spring - Summer)	Very Large, Purple or Red	Berries on Females, Red to Dark Blue	
Flowering	Small yellow clusters	Inconspicuous	8-10' White, Fragrant - After mature (Summer through Fall)	Inconspicuous	
Water	Low to Drought-Tolerant	Moderate - Deep & infrequent in clay, deep & frequent for sand	Moderate to Ample - Keep Moist with deep, heavy waterings	Any, prefers deep & infrequent	
Soil	Any, Needs good drainage, Tolerates Alkalinity	Well-Drained, Neutral to Slightly Acidic	Well-drained, rich, neutral or slightly acidic	Any, Prefers well-drained, Tolerates Alkalinity	
Sun	Filtered &/ or After-noon Shade	Full Sun Best	Full Sun	Full Sun to Part Shade	
Maintenance Concerns	Moderate Root Damage & Insect Potential, Needs Staking and Pruning	High Potential for Root Damage. Leaf and Fruit Drop, Needs Staking & Pruning	High Potential for Root Damage. Insect Possible, Needs Staking & Pruning, Flower & Fruit Drop.	Moderate Root Damage, Free of Most Insects and Diseases, Needs Staking and Pruning	
Comments	Takes clipping, spray for black scale & laurel psyllid, suckers heavily. Multi-trunked, dense & compact form. Fruit drop not suitable along sidewalks or streets.	Stake well, prune to shape. Use deep watering to keep surface roots down. Multi or single trunk, dense & compact form. Do not use near sidewalks or streets.	Add organic matter & watch for deficiency problems. Irregular form in maturity. Keep roots down with deep watering. Do not use near sidewalks or streets.	Stake & prune to shape when young. Irregular form when young, dense and compact with maturity. Use male clones, female fruits not suitable along sidewalks or streets.	

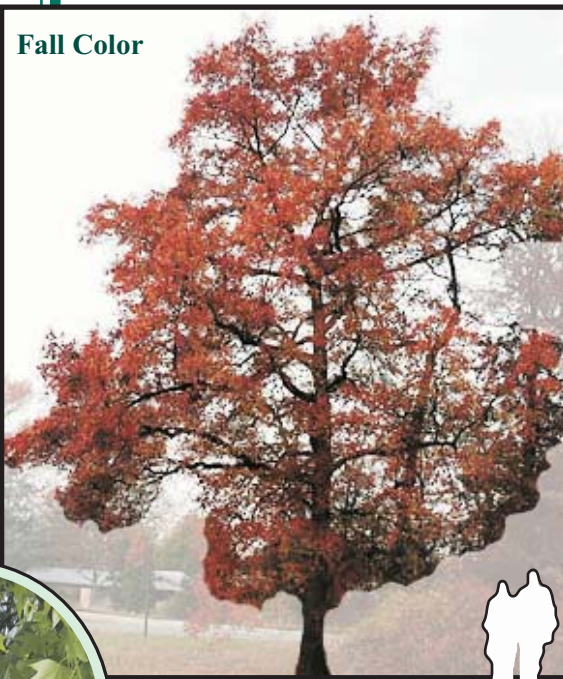


21. *Laurus nobilis*
Sweet Bay
(25' high x 25' wide)



23. *Magnolia grandiflora*
Southern Magnolia
(75' high x 30' wide)

Fall Color



22. *Liquidambar styraciflua*
American Sweet Gum
(50' high x 25' wide)



Fall Color



24. *Pistacia chinensis*
Chinese Pistache
(50' high x 40' wide)



Street Tree Photographs

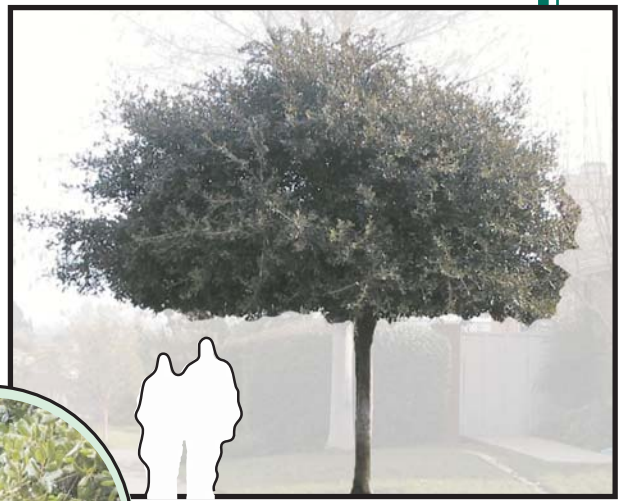


TREE NAME	Botanical Name	Platanus acerifolia	Pyrus calleryana	Quercus agrifolia	Quercus coccinea
	Common Name	London Plane Tree	Ornamental Pear	Coast Live Oak	Scarlet Oak
STREET TYPE	Medians & Cul-de-Sacs (A&E)				
	Residential & Local (E)				
	Industrial (D)				
	Commercial (C)				
	Collector (B)				
	Arterial (A)				
	Plant Photo Number (See Following Page)	25	26	27	28
Tree Size	Large	Medium to Large	Medium to Large	Large	
Growth Rate	Moderate to Fast	Moderate to Fast	Slow to Moderate	Moderate to Fast	
Planter Size	Minimum 25'	Minimum 17'	Minimum 25'	Minimum 20'	
Evergreen	No	No	Yes	No	
Canopy Shape	Round	Round	Round	Round/ Open	
Leaf Color and Texture	Green	Dark Green, very glossy & leathery	Green, Slightly Glossy	Bright Green	
Leaf Size & Shape	4-10", 3 to 5 lobes	1-3", oval, scalloped	1-3", Holly-Like	6", deeply cut, pointed lobes	
Fall Color	Bronze or Golden	Rich Purplish Red & Yellow	None	Bright Scarlet	
Fruits/ Berries/ Nuts	Medium Brown or Green (Summer)	Small, Round & inedible, Brown or Green	Large Brown (Fall to Winter)	Medium Brown (Fall to Winter)	
Flowering	Inconspicuous	White, small clusters (Very Early)	Inconspicuous	Inconspicuous	
Water	Any	Regular to Moderate	Any, Little when established	Moderate to Regular	
Soil	Tolerates most soils, Tolerates Alkalinity	Any, Tolerates Alkalinity	Any, Tolerates Slightly Alkaline	Deep and rich, Tolerates Alkalinity	
Sun	Full Sun to Part Shade	Full Sun to Part Shade	Full Sun to Part Shade	Full Sun to Part Shade	
Maintenance Concerns	High Potential for Root Damage, Diseases and Insects. Dry Fruit and Leaf Drop	Moderate Root Damage, Pest and Disease Potential. Wet Fruit Drop.	Roots Invasive and has a High Potential for Root Damage. Dry Fruit Drop.	Moderate Root Damage Potential, Dry Fruit Drop	
Comments	Tolerates smog, soot, dust, and reflected heat. Can be pollarded, Watch for spider mites, scale, and powdery mildew. Do not use near sidewalks or streets.	Subject to Fireblight, horizontally tiered branches create broad form in maturity. Fruit drop not suitable along sidewalks or streets.	Drops old leaves in early spring, irregular forms. Has invasive roots, Do not use near sidewalks or streets.	Roots grow deep, Fine to garden under, Open growth form.	

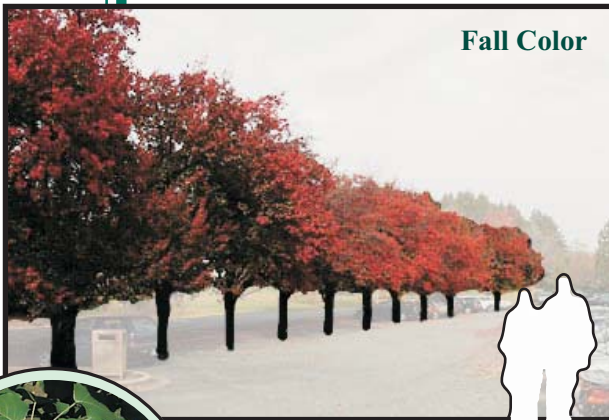
STREET TREE CHARACTERISTICS



**25. *Platanus acerifolia*
London Plane Tree
(60' high x 35' wide)**



**27. *Quercus agrifolia*
Coast Live Oak
(25-60' h x 35-75' w)**



Fall Color



**26. *Pyrus calleryana*
Ornamental Pear
(30-50' h x 25-35' w)**



**28. *Quercus coccinea*
Scarlet Oak
(70' high x 50' wide)**

Street Tree Photographs



TREE NAME	Botanical Name	Quercus ilex	Sapium sebiferum
	Common Name	Holly Oak	Chinese Tallow Tree
STREET TYPE	Medians & Cul-de-Sacs (A&E)		
	Residential & Local (E)		
	Industrial (D)		
	Commercial (C)		
	Collector (B)		
	Arterial (A)		
	Plant Photo Number (See Following Page)	29	30
	Tree Size	Large	Medium
Growth Rate	Moderate	Moderate to Fast	
Planter Size	Minimum 15'	Minimum 10'	
Evergreen	Yes	No	
Canopy Shape	Round	Round	
Leaf Color and Texture	Dark, rich green, yellow or silver below	Light Green	
Leaf Size & Shape	2-3", variable shape and form	Round, tapers to a point	
Fall Color	None	Variety and Mixture of Fall Colors	
Fruits/ Berries/ Nuts	Medium Brown (Summer/ Winter)	Small clustered, grayish white	
Flowering	Inconspicuous	Tiny yellow in spikes at branch tips	
Water	Little to Regular	Low to Moderate, Low best but ample for fast growth	
Soil	Tolerates Alkalinity	Most, prefers mildly acidic	
Sun	Full Sun to Part Shade	Full Sun to Part Shade	
Maintenance Concerns	Needs Staking and Pruning, Dry Fruit Drop.	Needs Staking & Pruning, Flowers & Dry Fruit Drop. Poisonous Seeds. Free of Most Pest & Diseases	
Comments	Very hardy tree. Variable growth depends on soil and water, takes clippings into formal shapes, irregular forms.	May require thinning, tends to sucker & be shrubby, easily trained, multi-trunked, dense & compact form. Fruit drop not suitable along sidewalks or streets.	



29. *Quercus ilex*
Holly Oak
(40-70' h x 40-70' w)



30. *Sapium sebiferum*
Chinese Tallow Tree
(30' high x 30' wide)

Street Tree Photographs



APPENDIX C:

Nursery Stock Specifications

Information from: Nursery Stock Specifications.

By Brian Kempf.

Produced by the Urban Tree Foundation.

Visalia, California.



NURSERY STOCK SPECIFICATIONS

I. Proper Identification

All trees shall be true to name as ordered or shown on the planting plans, and shall be labeled individually or in groups by species and cultivar (where appropriate). Refer to www.urbantree.org/specs.htm for more information.

II. Compliance

All trees shall comply with federal and state laws and regulations requiring inspections for plant disease, pests and weeds. Inspection certificates required by law shall accompany each shipment of plants. Clearance from the County Agricultural Commissioner, if required, shall be obtained before planting trees originating outside the county in which they are to be planted. Even though trees may conform to county, state and federal laws, the buyer may impose additional requirements.

III. Tree Characteristics at the Time of Sale or Delivery

A. Tree Health

As typical for the species/cultivar, tree shall be healthy and vigorous, as indicated by an inspection for the following:

- Foliar crown density
- Length of shoot growth (throughout crown)
- Size, color and appearance of leaves
- Uniform distribution of roots in the container media
- Appearance of roots
- Absence of twig and/or branch dieback
- Relative freedom from insects and diseases

Note: Some of these characteristics cannot be used to determine the health of deciduous trees during the dormant season.

B. Crown

1. Form: Trees shall have a symmetrical form as typical for the species/cultivar and growth form.



- a. **Central Leader:** Trees shall have a single, relatively straight central leader and tapered trunk, free of codominant stems and vigorous, upright branches that compete with the central leader. Ordinarily, the central leader should not have been headed. However, in cases where the original leader has been headed, an upright branch at least one-half the diameter of the original leader just below the pruning point shall be present.

Note: This section applies to single trunk trees, as typically used for street or landscape planting. These specifications do not apply to plants that have been specifically trained in the nursery, e.g., topiary, espalier, multi-stem, clump, etc. or unique selections such as contorted varieties.

- b. **Main Branches (Scaffolds):** Branches should be distributed radially around and vertically along the trunk, forming a generally symmetrical crown typical for the species. Minimum vertical spacing may be specified.
 1. Main branches, for the most part, shall be well spaced.
 2. Branch diameter shall be no larger than two-thirds the diameter of the trunk, measured 1" above the branch.
 3. The attachment of scaffold branches shall be free of included bark.
- c. **Temporary Branches:** Unless otherwise specified, small "temporary" branches should be present along the lower trunk below the lowest main (scaffold) branch, particularly for trees less than 1-1/2" in trunk diameter. Temporary branches should be distributed radially around and vertically along the lower trunk. They should be no greater than 3/8" in diameter and no greater than one-half the diameter of the trunk at the point of attachment. Heading of temporary branches is usually necessary to limit their growth.

C. Trunk

1. Trunk diameter and taper shall be sufficient so that the tree will remain vertical without the support of a nursery stake.
2. The trunk shall be free of wounds (except properly-made pruning cuts), sunburned areas, conks (fungal fruiting-bodies), wood cracks, bleeding areas, signs of boring insects, galls, cankers and/or lesions.



3. Trunk diameter at 6" above the soil surface shall be within the diameter range shown for each container size below:

<i>Container Size</i>	<i>Trunk Diameter (inches)</i>
#5	0.5" to 0.75"
#15	0.75" to 1.5"
24" box	1.5" to 2.5"

D. Roots

1. The trunk, root collar (root crown) and large roots shall be free of circling and/or kinked roots. Soil removal near the root collar may be necessary to inspect for circling and/or kinked roots.
2. The tree shall be well rooted in the soil mix. When the container is removed, the rootball shall remain intact. When the trunk is carefully lifted, both the trunk and root system shall move as one.
3. The upper-most roots or root collar shall be within 1" above or below the soil surface.
4. The rootball periphery should be free of large circling and bottom-matted roots. The acceptable diameter of circling peripheral roots depends on species and size of rootball. The maximum acceptable size should be indicated for the species (if necessary).

E. Moisture Status

At time of inspection and delivery, the rootball shall be moist throughout, and the tree crown shall show no signs of moisture stress, as indicated by wilt, shriveled, dead leaves, or bank die-back. Roots shall show no signs of being subjected to excess soil moisture conditions, as indicated by root discoloration, distortion, death or foul order.

IV. Inspection

The buyer reserves the right to reject trees that do not meet specifications as set forth in these guidelines or as adopted by the buyer. If a particular defect or sub-standard element or characteristic can be easily corrected, appropriate remedies shall be required. If destructive inspection of rootballs is to be done, the buyer and seller should have a prior agreement as to the time and place of inspection, minimum number of trees to be inspected or percentage of a species or cultivar, and financial responsibility for the inspected trees.



V. Delivery

The buyer should stipulate how many days prior to delivery that notification is needed.

GLOSSARY:

Condominant - Stems: Two or more vigorous and upright branches of relatively equal size that originate from a common point, usually where the leader has been lost or removed.

Crown: The portion of a tree above the lowest main (scaffold) branch, including the trunk, branches and foliage.

Cultivar: A named plant selection from which identical or nearly identical plants can be produced, usually by vegetative propagation or cloning.

Girdling Root: A root that partially or entirely encircles the trunk and/or large buttress roots, which could restrict growth and downward movement of photosynthate.

Included Bark: Bark embedded within the crotch between a branch and the trunk or between two or more stems that prevents the formation of a normal branch bark ridge. This often occurs in branches with narrow-angled attachments or branches resulting from the loss of the leader. Such attachments are weakly attached and subject to splitting out.

Kinked Root: A primary root (s), which is sharply bent, causing a restriction to water, nutrient and photosynthate movement. Kinked roots may compromise the structural stability of roots systems.

Leader: The dominant stem which usually develops into the main trunk. Photosynthate pertains to sugar and other carbohydrates that are produced by the foliage during photosynthesis, an energy trapping process.

Root Collar: The flared area at the base of a tree where the roots and trunk merge. Also referred to as the “root crown” or “root flare”.

Shall: Used to denote a practice that is mandatory.

Should: Used to denote a practice that is highly recommended.



Scaffold Branches: Large, main branches that form the main structure of the crown.

Temporary Branch: A small branch that is retained temporarily along the lower trunk of young trees. Temporary branches provide photosynthate to increase trunk caliper and taper and help protect it from sunburn damage and mechanical injury. Such branches should be kept small and gradually removed as the trunk develops.

Trunk: The main stem or axis of a tree that is supported and nourished by the roots and to which branches are attached.

For more information, contact:

Urban Tree Foundation
Brian Kempf
1512 W. Burrell Street
Visalia, CA 93291
559/713-0631
brian@urbantree.org



APPENDIX D:

Maintaining Street Trees

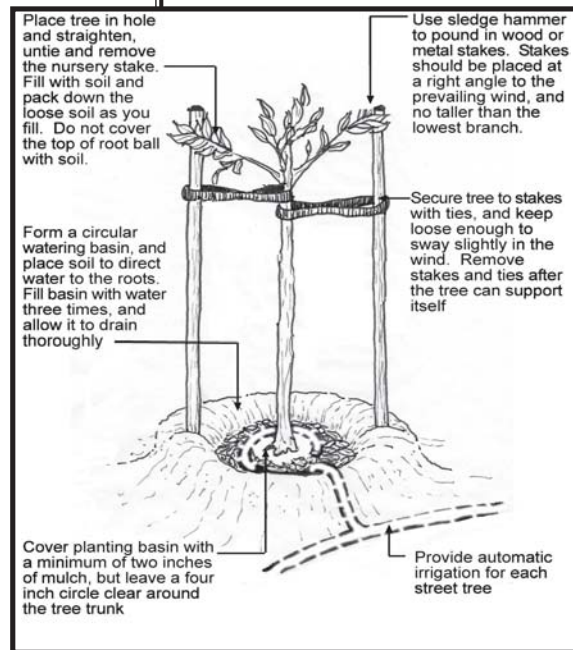
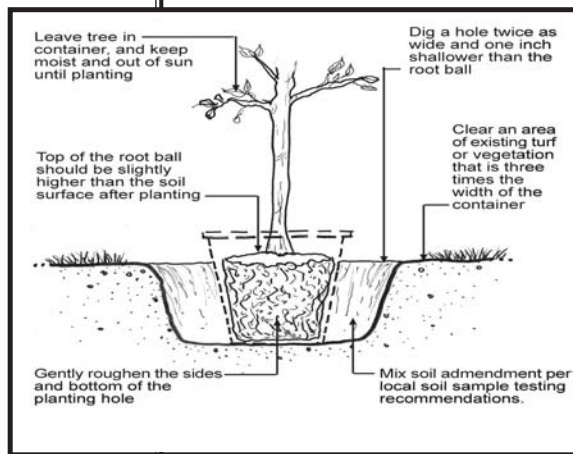


MAINTAINING STREET TREES

There is a variety of maintenance needed in the stages of a tree's life, and therefore this document can only begin to discuss the bare necessities. Consult books from garden centers or libraries for information as needed, or call the City's Parks and Recreation Department with specific maintenance questions.

Planting

Choose the appropriate tree size and form for your project. Make sure you are able to match the sun, soil, and watering requirements listed in the "Street Tree List" spreadsheet in Appendix B. Obtain planting details from the City's Parks and Recreation Department to ensure you are properly planting, mulching and staking the trees.



- November to January is the best time to plant trees; try not to plant in the hot summer months.
- Insert root deflection barrier panels in all planting areas located within 5 feet of hardscaping, buildings, walls, and underground utilities. Install barriers parallel to the elements needing protection.
- Stake and tie the tree at right angles to the prevailing wind direction, and keep it loose enough to allow the tree to sway slightly with the wind. Tree stake should not be taller than the lowest lateral branch.
- Install mower guards or tree grates, if needed, consult manufacturers specifications for installation methods.

Soil Preparation and Conditioning

- Dig a planting hole to a minimum of 30-inches deep and with a width a minimum of three times the diameter of the trees container. Generally, the hole should be twice the size of the tree's nursery container, and 1 inch shallower than the top of the tree's root ball.
- The height of the root ball should sit 1 to 2-inches higher than grade level to prevent settling and drowning the tree as it establishes itself. Make the hole deep enough to allow the root ball of the container to rest on the firm undisturbed soil.
- All debris fragments over 2-inches in diameter shall be removed from the planting hole to a minimum of 24-inch depth.
- Break up and loosen the soil on the sides and the bottom of the pit. The soil beneath the rootball should be packed down to prevent settling.

- Add soil amendments as needed based on the type of soil you will be planting in. Ask a registered Landscape Architect, licensed Landscape Contractor, University Agriculture Extension, or the Parks and Recreation Department if you are unsure of the amendment you need.
- Apply at least a 2 inch layer of mulch inside the planting hole, but keep the mulch a minimum of 2 inches away from the tree trunk. Reapply the mulch as needed throughout the life of the tree.

Drainage

- A percolation test shall be conducted to make sure water adequately drains away from the new trees. A minimum of one test per site shall be conducted and reviewed prior to tree installation. Locations with poor drainage can be improved with one of the following mitigation measures:
 - Install a French drain which radiates away from the tree, and make the grade fall away from the tree trunk.
 - Install drain tiles or perforated pipes which directs the water away from the tree.
- Perform a percolation test by checking the soil you will be planting in. Dig a 2 feet deep hole and fill it with water to see how quickly it drains. The water should drain a minimum 2 inches per hour. If you are unsure about your soil or have concerns, take a sample to a soil lab for testing. Sites with poor drainage will need reviewing by a registered Landscape Architect or Arborist, and may require additional testing.
- For trees to be planted in severely compacted soils, aeration tubes may be required. Aeration piping (rigid or flexible), may be necessary in sidewalk planters, planting strip, medians, or tree wells with compacted soils. Aeration tubes circle the bottom of the planter, and the number to use depends on the tree size you are planting and the soil composition (see the Aeration Tube Table). If you have compacted soils, ask the City's Park and Recreation Department for additional information about aeration tubes.

AERATION TUBE TABLE	
TREE SIZE	NUMBER OF TUBES
15 gallon trees	one tube
24' box trees	two tubes
36' box trees	two tubes
48' box trees or larger	four tubes or as needed

Watering

Water consumption by trees in a city is a critical factor in the selection, success and sustainability of the urban forest. Trees must be able to survive with the amount of water you will be providing, and you should first consider the quantity of water the tree needs, and the type of watering you will be delivering throughout its life cycle. Start by determining the amount of water your tree species needs based on the Street Tree List in Appendix B, refer to the Sunset Western Garden Book, or search <http://selectree.cagr.calpoly.edu/> for information on street trees not yet listed. Also, decide on the type of watering system you will be using for the trees based on the following information before you plant the street trees.

General Watering Guidelines

- There are many factors that contribute to a tree's watering requirements, and they should be considered before choosing the trees you will be planting. Soil properties, irrigation methods and performance, and microclimate variables such as wind and sun all affect the amount of water needed to sustain a tree.



- Test to see how quickly your soil drains, and/or have a soil test performed prior to planting your tree. Fill your planting hole with water and time how long it takes for the water to absorb into the soil. This will give you a general idea about the soil's water holding capacity. Note that soils vary greatly even on one piece of property and each hole should be tested.
- Check the soil moisture in the root ball after the tree is first watered and time how long it takes the soil to dry out. Schedule watering periods to allow the soil around the tree to dry out slightly, but not become completely void of water.
- Plant trees with a circular mound of soil around the planting hole. Direct the water towards the trunk of the tree, mulch and reestablish the mound as needed throughout the tree's lifetime.
- Water in early morning or late evening to slow evaporation rates.
- It is usually a good idea to plant and group trees with similar watering requirements. The trees can then be combined on the same irrigation valve and have a similar watering schedule.
- Irrigation should be checked in the spring of each year to make sure it is still working correctly.
- As the trees become established, you can water less frequently. The watering times and amount of moisture will vary on temperature and winds, but a general schedule is:
 - 1-3 months: Water when root ball soil becomes dry
 - After 3-6 months: Water twice a week
 - After 6-12 months: Water twice a month
 - After 1 year: Water every 3 to 4 weeks in cool seasons, and twice a month in hot times of the year.

Encourage Deep Roots

- It is always best to water thoroughly and frequently to encourage deep rooting in the soil. Try to wet the tree's entire root zone when watering, but do not apply too many heavy soakings. It is necessary to let the soil dry out slightly so that the tree will not drown. Test the soil, and if the top 3 to 4 inches of soil is dry, it is time to water again.
- Do not apply just light sprinklings because they can be very damaging. Roots develop only where water and nutrients can be found, and shallow watering tends to produce surface roots.
- Watering requirements will depend on the type of soil you are planting in. In most cases, clay soils drain slowly and hold more water, sandy soil drain faster, and loamy soils are somewhere in the middle.
- To wet tree roots to a depth of 6 feet, a general method of watering is:
 - Clay Soils: Fill the basin, let it drain, and then repeat 3 more times
 - Loam Soils: Fill the basin, let it drain, and then repeat 1 more time
 - Sandy Soils: Fill the basin only once



Irrigation Systems

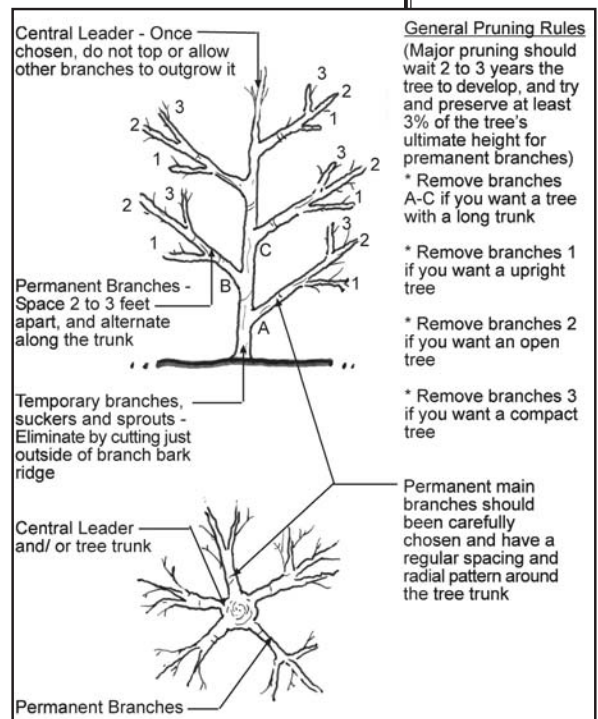
- Hand watering with a hose is an inexpensive method of irrigation, but it takes a lot of time and energy and is not a reliable long-term system. If a property owner moves or goes on vacation, the trees can become neglected and hand watering is therefore not recommended for street trees.
- Sprinkler systems are one of the simplest methods of watering and can quickly cover large areas. If improper design or system operation failures occur, sprinklers can contribute to the formation of surface roots, waste water by overspray and run-off, and can encourage foliage diseases.
- Drip irrigation systems are a good choice for street trees, and are relatively inexpensive and very adaptable. Drip systems apply the water directly to the location desired and make it easy to control the amount of water delivered to the tree. Drip systems are very flexible, and the drip emitters can be combined with spray heads and soaker tubing if needed.
- Check your water pressure before deciding on how you will be applying water, and make sure you have enough pressure to successfully run an irrigation system.
- Proper on-going system maintenance must be implemented to ensure successful long-term water application.
- Check with a local nursery or Landscape Architect if you have additional questions or concerns about watering and irrigation systems.

Pruning Trees

Pruning may be the most important maintenance duty to carry out on young trees if they are to become healthy mature specimens. The energy invested in training a young tree will be much less than corrective pruning of neglected adult trees. Waiting to prune a tree until it is fully developed could create the need for more substantial cuts, and make it very difficult for a tree to recover.

When planting young trees; prune only the weak, dead, or injured branches. Remove any torn or broken branches, but reserve other pruning for the second or third year. Pruning of new trees should be restricted to corrective pruning, and no more pruning should take place in one year than is needed to develop the form and strength of a tree.

When a tree is young, avoid removing the small side branches that develop along the trunk because they help the tree increase in size and create a sturdier trunk. Small cuts tend to do less harm to the tree than larger cuts, and by removing only the problem branches the young trees can use all their strength to develop a healthy root system. It was once believed that wound dressings speed up the healing of a pruned limb; however, recent research has shown that dressings do not reduce decay, and rarely prevent infestations.



Proper branch selection of a young tree is critical for a healthy trunk development

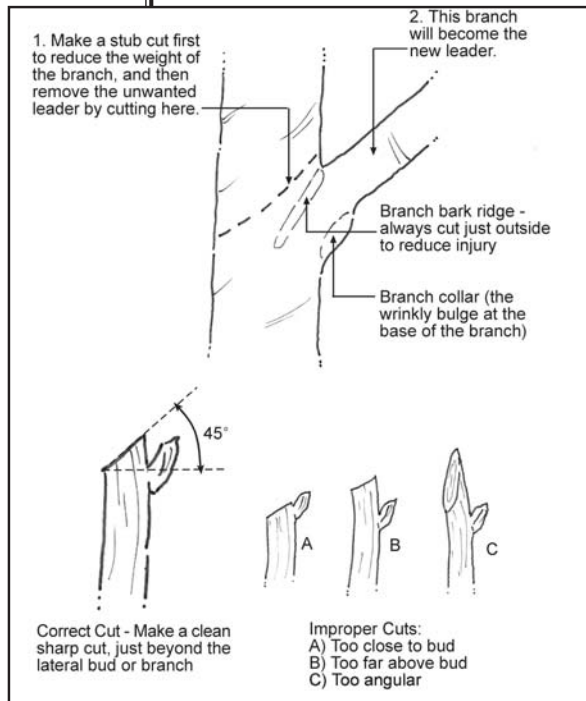
Most street trees will require pruning, and maintenance accessibility must be considered in tree placement. Proper pruning is essential to the health of the trees, and correct pruning techniques must be researched and incorporated into the maintenance of the trees.

General Pruning Rules

- Prune evergreen trees in late fall, and deciduous trees when all their leaves have dropped. This may vary in emergency situations, but it is best to prune when the tree is dormant.
- Trees planted along sidewalks, roadways, bikeways and parking areas must have their lower branches pruned up above the height of passing traffic. These branch heights must be maintained throughout the tree's life (See Sections for Street Types in Appendix A).
- Generally do not prune:
 - The top of a tree
 - The lower branches of a tree, except for necessary clearance

Trunk Development

When training a new tree, first identify the main limbs that will ultimately make up the tree's skeleton. Unless the tree has a natural multi-stemmed pattern, most young trees should be trained to a single central leader. Select main limbs that have open angles of connection to the trunk, even spacing, and radial distribution around the trunk. Optimally, major limbs should be spaced 24 to 36 inches apart on alternating sides of the trunk. Trees with major branches occurring in pairs across the main stem can be pruned alternately up to a height of 12 to 18 feet.



Correct pruning methods for young trees

The central leader is the topmost vertical stem extending from the trunk. Do not prune the tip of this leader, or allow less important branches to outgrow it. Sometimes a tree will develop two or more leaders; and if their growth is allowed to continue, it could lead to structural weakness, so it is best to eliminate them while the tree is small.

Never cut the main branches back to stubs, or cut the tops off a tree ("topping"). Many people mistakenly top trees because they are growing too tall. Unfortunately, the topping the tree is self-defeating, and studies have shown that topping reduces the tree's nutrient production, makes the tree more vulnerable to attacks by insects and diseases, and unwanted and weak limbs usually grow back even taller than the cut branch. Proper pruning can alleviate unnecessary growth, and eliminate the problems topping creates.

Branch Selection

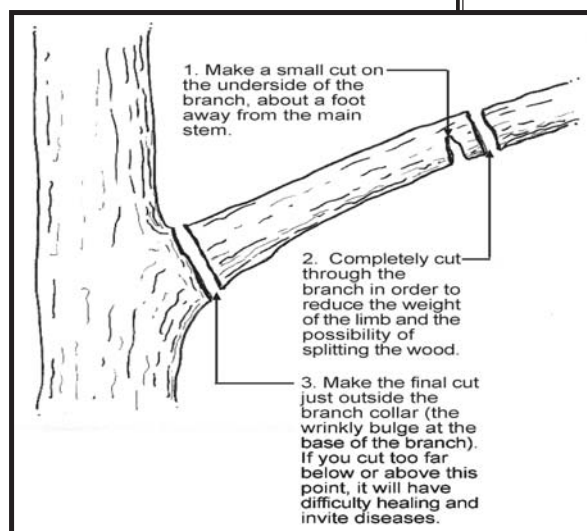
Lateral branches add to the growth of a strong trunk, and during the tree's early development it is vital to leave some temporary branches on the tree at lower than the eventually branch height desired. These are temporary branches which will help protect the trunk from sun and injury, but need to be kept small enough not to be in the way or compete with the chosen permanent branches.

The choice and spacing of permanent branches on and around the trunk is very important. Branches selected as permanent branches must be properly located along the trunk, and preserve a sense of balance with branches by allowing them to grow outwards in each direction. The permanent branches should be vigorous, and have a stem diameter of 1/2-inch or less where the branch attaches to the trunk. Remove any laterals that have grown inward toward the center of the crown, higher than the main leader or beyond the crown. Never let one limb grow directly over a lower one, and prune back laterals that grow taller than the leader. Eliminate the weak sprouts and suckers off the trunk, and always cut just outside of the branch bark ridge to reduce injury to the branch collar.

Avoid pruning too much of the interior canopy of the tree because the foliage on each limb must produce enough nutrients to keep that branch growing. Pruning of too many leaves can damage the tree and lessen its maturity, and try to keep at least one-half of the leaves on the branches on the lower two-thirds of the tree, and try to maintain at least 3 percent of the tree's ultimate height for the vertical spacing of permanent branches. Stagger the branches so that they do not occur over one another on the same side of the trunk. For example, a tree that will reach 50 feet in height should have the permanent branches alternating, and occurring 15 inches away from each other along the trunk.

Pruning Tips for Young and Mature Trees

- Prune when the trees are dormant (usually December to February) to have the least amount of harm to the tree.
- Use strong enough tools for the job: pruning shears for small cuts, loppers for limbs thicker than a broom handle, and saws for more mature branches.
- Never use dull tools, and switch to another tool if you can't cut the branch easily.
- Thoroughly clean tools with rubbing alcohol after pruning to prevent the transfer of pests and/or diseases between trees.
- Generally do not prune more than 25 percent of a young tree's canopy in one year. As the trees grow, be prepared to reevaluate your branch selection.
- For larger branches, use the three-step cutting process shown in the Pruning Methods for Mature Tree Branches to avoid wounding the tree.



Pruning methods for mature tree branches

- Tie string on the branches you are considering keeping, step back and look at them, and then cut.
- Remove any excessive growth which interferes with the leader and permanent branches, but prune in a manner which allows the tree's natural form to continue to develop.
- Consider how large a tree will ultimately become before planting, and do not attempt to make the tree fit to your site by excessive pruning.
- Consult a professional Arborist, Landscape Architect, or certified Nurseryman if you have any additional questions or pruning needs not covered in this text.



APPENDIX E:

Structural Soil Specifications

Information from: LATIS, Structural Soils.

By Jason Graboskym Nina Bassuk, and Peter Trowbridge.

Published by the American Society of Landscape Architects.

Washington DC. 1999.



STRUCTURAL SOILS: A NEW MEDIUM TO ALLOW URBAN TREES TO GROW IN PAVEMENT

Description of the Problem

The fact that trees have difficulties surviving amid the conditions of urban and suburban environments is not a surprise. Urban areas for the most part are not designed with trees in mind. They are often treated as if they were afterthoughts to an environment built for cars, pedestrians, buildings, roadways, sidewalks and utilities. Studies point out that trees surrounded by pavement in the most urban downtown centers live for an average of 7 years (Moll, 1989; Craul, 1992; American Forests, 1997), while those in tree lawns, those narrow strips of green running between the curb and sidewalk, live up to 32 years. These same species might be expected to live anywhere from 60 to 200 years in a more hospitable setting.

Why is this so?

Urban trees experience a virtual litany of environmental insults such as increased heat loads, de-icing salts, soil and air pollution and interference from utilities, vehicles and buildings (Bassuk, Whitlow, 1985; Brady, 1990; Craul, 1992). Yet the most significant problem that urban trees face is the scarce quantity of useable soil for root growth (Lindsey, Bassuk, 1992). A large volume of non-compacted soil, with adequate drainage, aeration, and reasonable fertility, is the key to the healthy growth of trees (Perry, 1982; Craul, 1992). The investment in soil for a healthy tree is paid back by fulfilling the functions for which it was planted. These functions may include shade, beauty, noise reduction, wind abatement, pollution reduction, wildlife habitat and the creation of civic identity (Heisler, 1974; McPherson, et. al., 1994). An adequate soil volume is key considering soils are where nutrients, water and air are held in a balance that allows for root growth, water and nutrient acquisition. Simply put, when soils are inadequate, plant growth suffers and trees die prematurely.

Soil Terminology

The usefulness of any given soil is largely dictated by its texture, structure and fertility. Soil texture or the percentage of sand, silt and clay in a given soil type, is an important parameter to define. Several soil characteristics, including sand, silt, clay and organic matter make up the solid portion of soil, while water and air make up the rest. Nutrient-holding capability is regulated by the proportional amount of clays and organic material in the soil. A soil's susceptibility to compaction will be determined by the soil's particle size distribution and the total amounts of silts and clays in the soil. Soil hydraulic characteristics, including moisture-holding, aeration and drainage, will be determined, in part, by the types of soil particles present in the soil matrix. The compacted bearing capacity, frost-heave potential, and other engineering characteristics are intrinsically tied to the soil texture.

Beyond soil texture, soil structure which is the aggregation of individual sand, silt and clay particles into larger clumps called peds, heavily influences the agricultural viability of a soil. Within these aggregates, water may be held against the force of gravity, making it available to the plant's roots. Good structure or well aggregated soils provides pores that allow water



to drain and aeration of the root zone to take place. Human activities can severely damage soil structure.

The process of building in a city, or even installation of a sidewalk in an otherwise rural area, necessarily dictates a high level of soil disturbance. Any construction effort requires soil excavation, cut and fill, re-grading and soil compaction. Often highly efficient heavy machinery is brought on site to accomplish this work increasing the potential for compaction of soils (Randrup, 1997). There are two critical effects of soil compaction which directly impact plant growth. 1) Soil structure is destroyed, crushing the majority of large interconnected pores (macro pores) which restrict water drainage and subsequent aeration. 2) As the macro pores are crushed, soils become denser, eventually posing a physical barrier to root penetration. There are numerous accounts of urban soils being literally as “dense as bricks” (Patterson, 1980).

One method of evaluating relative compactness, or the severity of soil compaction, is to measure the soil’s weight per volume, or its density. This measurement is communicated either by bulk density or by dry density. Dry density is the dry weight of soil per a given volume, often expressed as grams dry weight/cm³ (g cm⁻³ or Mg m³). Soils, depending on their texture, become limiting to root growth when their dry density approaches 1.4 g cm³ for clayey soils to 1.7 g cm³ for sandy soils (Morris and Lowry, 1988). When roots encounter a soil so dense that they cannot penetrate it, the roots may change direction if that is possible, or be stopped from growing altogether. Very often in the urban environment, roots coming out of a newly planted root ball into compacted soil will grow from a depth of 12 or 18 inches up where they remain just below the surface (Grabosky-Bassuk, unpublished data). This superficial rooting tends to make urban trees more sensitive to drought as soils dry out in the summer (Bassuk-Whitlow, 1985).

Conversely, when a tree is planted into compacted soil and drainage is impeded through the crushing of soil macro pores, water may remain around the root zone depriving the roots of needed oxygen. This can lead to root death and an impaired ability to take up water and nutrients that are necessary for tree growth.

In urban soils that are not covered by pavement, it is possible to cultivate, amend or replace compacted soils to make them more conducive to root growth. However, where soils are covered by pavement, the needs of the tree come in direct opposition to specifications that call for a highly compacted base on which to lay pavement. All pavements must be laid on well draining compacted bases so that the pavement will not subside, frost heave, or otherwise prematurely require replacement. What is Proctor density?

In order to create predictably compacted base course materials, a test is typically used called ‘Proctor density’ or ‘peak density’. This assures that the base below the pavement is compacted sufficiently to meet the wear that it will receive. For any type of soil or aggregate, Proctor density is defined by ASTM D 698-91 method D protocol. The soil type to be used is tested with the same amount of compactive effort, 56 blows from a 5.5 pound hammer free-falling 12 inches for each of 3 layers in a 6 inch diameter mold of 4.6 inch depth, at different moisture content. As the soil moisture content increases, the standard Proctor effort will result in a higher soil dry density as water in the soil acts as a lubricant, allowing soil particles to pack and nest closer to one



another. The end result is an increase in dry density or dry-weight per volume, of the sample. Eventually, there will come a moisture level where the water in the soil actually holds the soil solids apart, resulting in a lower dry density after the standardized compaction effort. This relationship of soil dry density resultant from a standardized compact effort, over a range of moisture contents, can be graphed as a moisture-density curve. The maximum estimated dry density from the moisture-density curve is defined as 100% Proctor density. The actual dry density at 100% Proctor will vary depending on soil texture or stone aggregate size distribution. In the field, it is often required that soils or bases under pavement be compacted to within 95% Proctor density. This means that soils are often at dry densities greater than 1.8 or 1.9 g cm³. Thus, soils, that must support pavement are often too dense for root growth. It is not surprising then that urban trees surrounded by pavement have the shortest life span in cities (Moll, 1989 Craul, 1992; American Forests, 1997; McPherson et. at. 1994). Simultaneously, these paved areas also tend to be those that need trees the most to mitigate the heat island microclimate that exist in downtown areas.

How much soil volume does a tree need?

If it is recognized that urban trees are desired and necessary to the health and livability of our cities, how much useable soil is necessary to allow them to fulfill their design functions? Research at Cornell's Urban Horticulture Institute (UHI) has shown that a reasonable 'rule of thumb' for most of the United States, except for the desert southwest, is to plan for two cubic feet of soil per every square foot of crown projection. The crown projection is the area under the drip line of the tree (Lindsey and Bassuk, 1991). If the tree canopy is viewed as symmetrical, the crown projection can be calculated as the area of a circle (Pi x radius squared). For example: for a tree with a canopy diameter of 20 feet, the crown projection would be, 3.14 (10 squared), or 3.14 (100) = 314 square feet. Using the 'rule of thumb' an estimate can be calculated that the tree needs 628 cubic feet of soil to support it. Assuming a useable rooting depth of 3 feet, one way of dimensioning the space needed for this tree would be 21' x 10' x 3', or 630 cubic feet. It is clear that the typical 4' x 5' tree opening in the sidewalks, or the 6' x 6' tree pit is inadequate to allow the tree to fulfill its function in the landscape.

Where can one find enough soil?

Under the sidewalk there is a potential for a large volume of soil that would be adequate to allow trees to reach their 'design size' as long as the soil volume for each tree was connected and continuous, giving each tree a chance to share soil with its neighboring tree. Looking at the forest as a model, trees may be spaced reasonably close together as long as they share a large common soil volume to support their needs. Therefore, the task is to find a soil that meets a pavements design requirements while simultaneously allowing for unimpeded root growth under the pavement. To do this, the authors envisioned a two-part, or gap-graded, soil system that could be compacted to 100% Proctor density while still allowing roots to grow through it. The primary component of this "soil" system is a uniformly sized, highly angular crushed stone or crushed gravel. Ranging from 1 to 1 1/2 inches in diameter with no fine materials. If this single-sized stone is compacted, the stones would form an open stone skeleton with about a 40 percent porosity. For a similar single-sized spherical stone, a structure with 33 percent porosity would be produced (Shergold, 1953). Friction between the



stones at contact points would “lock in” forming the load-bearing structure of the mixture. The second component of this mixture is a soil which partially fills the stone voids. As long as we do not prevent the stone structure from forming by adding too much soil, the soil in the voids will remain largely non-compacted and root penetrable.

Structural Soils: How do they work?

Structural soil mixes are two-phase systems comprised of a stone skeleton or lattice for strength and soil for horticultural needs. Structural soils depend on a load-bearing stone skeleton to support the pavement. The lattice provides stability through stone-to-stone contacts while providing interconnected voids for root penetration, air, and water movement. The friction between the stones provides the strength. A narrow particle size distribution of the stone is chosen to provide a uniform system of high porosity after compaction. The system assumes full compaction to construction standards. Angular stone is selected to increase the porosity of the compacted stone lattice. As the stone is the load-bearing component of the system, the aggregates should meet regional Department of Transportation aggregate soundness and durability requirements for pavement base aggregates.

The soil in the design mixture should be a loam to heavy clay loam, lacking in all but fine sands. The soil in the system will be present in small amounts so as not to interfere with the stone lattice. Organic materials are not used in modifying the soil for use in a structural soil system at this point since they are generally avoided in normal pavement material selection. As a result, clay materials are needed for nutrient-holding and water-holding capacity. By carefully choosing the stone, soil and mixing ratio, we can create a gap-graded material able to provide the air and water balance necessary for root growth and plant establishment. The soil should also meet nutritional soil requirements for plant growth. The objective is to partially fill the stone lattice voids with soil. The soil is meant to coat the stones and reside within the stone lattice. The compaction of the mixture would form the stone structure while the soil in between the stones remains largely non-compacted. The intention is to “suspend” the soil between the stones, which come together during compaction, producing a load-bearing, compacted stone lattice with uncompacted soil in the voids. When properly designed and compacted, the system will have large voids providing room for root growth and aeration of the root zone.

To accomplish the objective, the ratio of soil-to-stone materials is a major consideration. If the stone voids are completely filled, aeration and bearing capacity of the system are compromised. Variability during the mixing process can occur, creating a mixture that is over-filled with soil. For any given stone, the addition of soil will change the formation of the stone lattice. This change in the lattice results in an unacceptable decrease in bearing capacity if over-filled with soil. One cannot simply estimate the voids in a compacted bucket of stone and add an equal amount of soil, and expect success for stability or plant establishment.

Any structural soil mix should assume compaction normally expected in construction of pavement sections. Compaction is often specified as a percentage of a peak density from a standard moisture-density curve (such as Proctor density) or a specified testing protocol (such as AASHTO T-99). Compacting to 95 percent peak density in this manner only gauges relative compactness, and does not imply 5 percent porosity. This density measure gives a quality control



mechanism to measure compactness and serves as a benchmark from which to evaluate the material for other engineering behaviors, such as bearing capacity, hydraulic conductivity, and plant available moisture in a system expected in the field.

The bearing capacity of the material is important, since the materials will be under large portions of pavement, and may need to support vehicular traffic. The bearing capacity can also influence the thickness, and thus the cost, of the pavement. One criterion of use is the California Bearing Ratio (CBR) which can relate to other pavement design parameters such as modules of sub-grade reaction. This method gauges the bearing capacity of a material by comparing it to a standard material known to be acceptable. For ease in pavement design protocol, it would be advisable to require a CBR greater than 50 in structural soil. The result is a material which can be compacted and provide a more stable base than found in many current sidewalk installations. This translates into a durable pavement design that can support tree establishment.

Testing for horticultural viability entails testing and observation of plant response over a period of time. Empirical data on plant response and growth analysis in controlled system applications remain the best method for evaluation. Research at UHI has shown that trees can grow well in structural soil mixtures (Grabosky, 1995, 1996, 1999).

One problem in designing the system is getting the mixture to blend uniformly and remain so during shipping, placement, and compaction. Due to mixing variation, it is not advisable to simply assign the maximum amount of soil possible. In fact, there is an observed loss in acceptable bearing capacity before the non-compacted soil fills the stone voids. This phenomenon has been observed when the mixture's compacted stone lattice becomes 65% filled with a soil calculated from the soil's premixed bulk density (Grabosky 1999).

At UHI, it has been found that the structural soil process benefits from adding a tackifying agent to stabilize the mixing process (Grabosky 1995). The tackifier allows for the stones and soil to mix more uniformly and prevents separation of the materials resulting from vibration in transit, dumping, and the working of the material in installation. Potassium propenoate-propenamide copolymer, agricultural hydrogel, has been used as tackifier with success.

Mixing Methods

To determine the ratio of stone to soil it is advisable to make three small test blends of slightly different ratios. A useful starting point is 15 percent to 20 percent soil by weight. We have found it best to define and control mixing ratios on a weight basis. Weight ratios avoid the difficulties encountered by variable volume-to-weight relationships and the changes in density of a given soil relative to its depth in a stockpile moisture content or its handling. The hydrogel is included at very low rates and is held at a constant rate relative to the stone for mix design purposes. These materials can then be tested to develop their respective moisture-density relationships (per ASSHTO T-99) and provide a compaction protocol. The materials can then be tested for their respective California Bearing Ratio at their expected installed densities. The results will give a base-line guide as to how much soil can be safely included in the mix design. Our experience in research trials at UHI has been that if the structural soil



meets the bearing capacity criterion of CBR greater than 50, at peak ASTM D 698 (AASHTO T-99) density, tree roots can penetrate and trees can be established successfully. The field compaction criterion for acceptance necessarily requires 95 percent peak density.

Once the mix ratio is identified there are two methods of mixing. The first is mixing on the flat with a front-end loader. In this method, the stone is spread into a layer on a paved surface, the hydrogel is evenly spread onto the stone, followed by a moist soil layer. This layered approach could be repeated into a six-layer pile if the loader is large enough to effectively mix the material. Then the layered system is turned and mixed until uniformly blended. If the system is too dry, additional moisture may be added to assist in mixing. The hydrogel could also be distributed as a slurry to help in this regard. The material should not exceed its optimal moisture content for compaction (determined from the moisture-density curve).

The drawback to mixing on the flat is that the mixing occurs on a volumetric basis. This requires knowing the volume of a “bucket-load” of material and its weight to convert into a weight ratio. The soil density varies as the material is taken from the soil stockpile. This means the weight per unit volume may change as the project progresses, changing the mixing ratio. This can be overcome by knowing the total stockpile weight and mixing the total with the appropriate weight of stone, and mixing the total project in batches. The batches are placed into a common pile and mixed again for consistency. This method requires little investment in equipment for a municipality, as most have the machinery to mix the materials. This approach is geared to small projects, limited to 600 cubic yards of material or less. If the mixing operation requires using or stockpiling larger quantities, there are mixing labor expenses and mixture consistency issues to contend with which may limit this mixing approach.

A second approach would be to use a pug mill. Pug-mill operations could mix structural soils on a weight basis with the ability to adjust moisture levels. The mixing contractor is likely to be familiar with the location or availability of pavement testing facilities. The milling operation can mix large quantities of material in a far shorter time period with the ability to apply quality controls.

Appropriate Usage

Structural soils in the context of this discussion have specific uses. The material supports pavement designed to withstand pedestrian and vehicular traffic. The materials can be designed for use under pedestrian malls, sidewalks, parking lots, and possibly some low-use access roads. The material is intended as a tool to be used when there are no other design solutions to provide adequate soil volumes for trees in close proximity to pavement.

Structural soils can be used as base material under pavement. The base material can be designed to act as a root exclusion layer to buffer the pavement from the pressures generated from expanding roots in secondary radial growth. While there is no definitive data related to radial root expansion to logically assign a base thickness, our research has shown that tree roots in structural soil profiles grow deep into the material below the pavement. The same research showed a lack of root development in the surface 12 inches below the pavement surface. It is anticipated that moving the roots down to the sub-grade will distribute those root pressures over



a wider section of pavement, reducing or eliminating sidewalk heaving.

By design, structural soils are fully compacted with conventional equipment to standard relative compactness (full Proctor density). Also by design, it can serve as the sub-base for the entire pavement section. Where there is a tree to be installed, the material can be allowed to rise to surface grade where the trunk pavement opening will occur. This provides an opportunity for watering, drainage, and passive aeration systems to the surface as well.

Below the pavement there can also be a base material of well-graded large aggregate that should possess no fine sands, silts or clays. This standard base layer could be to a depth normal for regional installation protocol or six inches. To discourage rooting in this layer, a geo-textile may be used between this base and the structural soil sub-base. The geo-textile should not restrict water movement. The sub-base is the structural soil material, in a layer thickness of 18 to 36 inches. Research studies are planned to determine cost-effective layer thickness.

Provision for an irrigation-aeration system between the base and sub-base materials may be considered. Given the large volume of structural soil for tree roots to explore, this need for irrigation is a long-term view of future management needs that needs to be evaluated as the tree eventually matures. While there is less moisture in a structural soil on a per volume basis, the total root system occupies most of the pavement area. Fertilization can be dissolved into the irrigation water for nutritional management. There must also be positive drainage provided to prevent water-logging. The sub-grade below the structural soil will still be compacted and rendered essentially impermeable to moisture. A perforated drain connected to the storm drainage system should be placed between the structural soil material and the compacted sub-grade.

Plant selection for structural soils should aid toward alkaline-tolerant and drought tolerant plant species. The pH of the system will be immediately dominated by the soil chosen. The stone used, whether limestone or granite, will heavily influence pH. However, if the system is paved with concrete products, the pH will continue to climb as the concrete slowly breaks down. A structural soil system provides an opportunity for choosing alkaline-tolerant species that do not respond well to compacted soil and its effects on root-soil processes.

Planting a tree into structural soil is fairly simple. The pavement opening is expanded to 6 by 6 feet to allow for buttress root formation on older trees. The wider opening could be paved in removable pavers. The tree is simply planted into the structural soil as it would be in a normal, albeit very stony, field situation. The roots would be expected to immediately contact the structural soil and grow into the material. It is presumed that supplemental irrigation will be provided during the first growing season.

Reasons for Caution

Many individuals have employed systems termed 'structural soils'. Indeed, our effort may have contributed to the term's popular usage. As all soils possess a structural component, the term structural soil is conceptually useful to identify a product but ill-suited to describe the



material. Many similar structural materials have been used with great success representing a wide range of stone-soil ratios, with and without stabilizing materials, but very few have been formally tested with both pavement and plant considerations. Several installations in British Columbia, Canada; Cincinnati, OH; Atlanta Olympic Park; Sydney Australia Olympic Park; and Brisbane, Australia, have demonstrated the viability of the approach in various forms. There have been several less successful and outright failures with conceptually similar installations as well. Of those tested, the Danish Institute of Forest Research and Cornell University Urban Horticulture Institute have reached many of the same conclusions independently. The final result is that many similar but different materials all fall under one conceptual term, structural soil, and not all of them work well.

Given the costs of failure, it is imperative to test any material appropriately with the involvement of the pavement design engineer. Our experience is that the system is more sensitive to pavement needs than to plant needs. As such, the most common miscues in execution of a structural soil system are excessive soil and the inclusion of organic amendments without proper testing. Without thorough testing to define a compaction level or any control of compaction, installations may, or may not, be structurally sound or horticulturally viable. Without a compaction test during mix design, one cannot know what aeration and root impedance issues lie ahead after installation. Our testing has shown little variation of plant establishment response over a wide mix ratio range. The root zone can be managed with irrigation and nutritional supplements over time, but it is expensive to lose and replace pavement prematurely. It is good planning to err on the side of pavement stability as it can be demonstrated to simultaneously provide a root zone to manage.

The structural soils developed and tested at Cornell University have been patented and are available through licensed distributors of CU Soil® in the United States. The intent has been to allow licensing to companies that can design, test and mix appropriate materials to provide a known product in quantity. CU Soil® distributors will have to provide the compaction data and specification, and CBR testing results of the material for installing contractors, site testing engineers, and landscape architects. The licensees will also have the results of ongoing research into the materials incorporated into their program to accommodate this new and developing methodology. Information on licensing can be obtained from:

Amereq Inc.
19 Squadron Boulevard
New City, NY 10956
(telephone 914-634-2400 or 1-800-832-8788)

FREQUENTLY ASKED QUESTIONS:

What happens when the hydrogel breaks down over time?

The hydrogel in the system is used to stabilize the mixture during the mixing, placement, and compaction phases of installation. There is no data on the expected life expectancy of hydrogels in general in structural soil systems under pavement. This situation is much different than more traditional soils and media in which hydrogels have been employed. While testing is needed, we



have observed intact hydrogel during excavation of test profiles four years after mixing. What happens when it breaks down? It reverts to the potassium salts and acrylamides from which it was produced. There will be the potential for soil movement due to vibration, but after the period of time required for loss of hydrogel efficacy, we are hoping to have a stable material, colonized by roots and other organisms which could replace the spatial and tackifying roles of the hydrogel.

What happens when roots expand in CU Soil?

We have seen roots deform to move around the stone structure, rather than displace the stones. There will come a time where the roots will likely displace the stone structure in the system. If we can move the roots down deep into the profile, the pressure they generate during expansion could be spread over a larger surface at the bottom of the pavement slab. With the appropriate thickness of the base course and pavement, the pressure could be accommodated within the strength of the pavement. There is no data on the radial expansion pressure generated by roots in secondary growth which account for the non-uniform pressure distribution, and plasticity a root can exhibit. We need more information to define a depth of the base material, since models for loading stresses upward on pavement need development.

Can you add normal soil in the tree pit and CU Soil under the pavement?

This is not necessary and is not recommended. The material is designed to be horticulturally sound, and our research has shown its ability to allow fast establishment. There would be the increase in material and labor costs to excavate and replace material after compaction. By adding the soil, you would produce a soil interface between the CU Soil ® and the backfill. This is definitely not a positive effect, and could be detrimental. Using a structural soil to directly plant in also allows for a firm base for unit pavers close to the root ball.

Is CU Soil susceptible to frost heave?

This topic has not been rigorously tested. The mix design of CU Soil ® should produce an extremely porous material. The original mix designs were approached in a manner to produce a material deemed low in frost susceptibility by US Army Corps of Engineers Cold Regions Research and Engineering Laboratory publications. We have not formally tested for frost heave potential, nor we have we observed frost heave damage in the several Ithaca, NY installations. The Central Avenue, Cornell Campus installation does accommodate occasional heavy vehicle and emergency traffic at all times during the year. There has been no stability problem to date on the rather thick 8 inch pavement. Based on drainage testing and swell data from compacted laboratory samples, the material appears to be quite stable. Can you use balled-and-burlapped, bare-root, or containerized trees in structural soils?

You can use trees from any production technique in CU Soil ®, and they have been used successfully. What is important is to think about the watering requirements for a newly transplanted tree.

What are the longest installations of CU Soil, and where are they?



The two oldest installations of hydrogel-stabilized, structural soil materials based on our research, with which we have any experience, were installed in 1994. These two projects were based on our early experimental results. The first one completed was part of the Staten Island Esplanade Project by the Staten Island Coast Guard Barracks. Honeylocust were planted into the structural soil on that project. The second project was for the Central Avenue on the Cornell Campus. London Plane trees were installed on that project. That same year, our first field experiment was under construction. The project was concluded and destroyed in 1997 - 1998. There was no aggregate migration of hydrogel within that 4 - 5 year period. There are numerous installations of various sizes across the United States and Canada. We are slated to be using CU Soil ® on the Boston Tunnel Project.

Can you add irrigation to structural soils?

Yes, and it would be encouraged for the eventual water demands of a more mature tree. Methods of water delivery are part of our current research. We would optimally have an irrigation/passive aeration system between the pavement base and the CU Soil ® sub-base. Such a system would minimize or nearly eliminate the need for access points in the pavement surface distant from the tree opening in the pavement. This necessitates drainage at the bottom of the CU Soil ® layer to prevent a build-up of moisture in the root zone.

Can you store large quantities of CU Soil, or do you have to make it fresh?

It would be preferable to not store the material in large stockpiles. The reality is a necessity to stock the material if production is to be cost efficient. The danger is a lack of aeration at the center base of a 400 cubic yard stockpile if kept exposed during a wet season such as winter-spring in much of this country. Turning the pile and blending to aerate the pile should overcome this difficulty. If a fertilizing agent is added to the CU Soil ®, consideration to moisture, time, and temperature impact the shelf life of the individual stock pile.

Should this be used in urban areas without pavement over the root zone?

It would not be cost-effective, nor the best design solution for any application other than supporting a paved surface scheduled to meet pedestrian, maintenance, and possible emergency vehicle traffic, or parking lot applications. Each situation is more-or-less unique, and no single design tool should be used as a broad-based design solution.

What is the minimum and maximum recommended depth for placing CU Soil?

We would suggest a six-inch base material layer and a minimum eighteen inch thickness of the CU Soil ® layer. Maximum depth of installation has not been tested; however, 36 inches is a reasonable lower limit. The reality is a cost-driven excavation decision process. Often, infrastructure would limit the layer thickness, since there is no desire to encourage working a CU Soil ® installation around pipes, wires, and conduits. We do not know how deep roots will effectively colonize a structural soil profile, but our field experiment visually suggested they would have no problem going deeper than the 24 inch CU Soil ® profile provided in the study.

What is the minimum recommended length and width for placing CU Soil?



There is no established minimum. One should consider several factors. CU Soil ® was designed to go under the entire pavement section. Utility considerations may influence location of some root zone encouragement. The material under a pavement section is preferably homogenous to prevent differential engineering characteristics below the pavement, particularly in regards to frost movement and drainage. The installation should focus on a whole sidewalk section or even a whole block.

Won't the soil migrate down through a structural soil profile after installation?

As mentioned earlier, the excavation of a relatively old installation did not show any aggregate migration. This area of vibratory effects on the system over time is in need of investigation. The hydrogel has an influence on this, hence its use in the design of CU Soil ®. The long-term stability will then be influenced on the hydrogel's effective life within this system. It will also be influenced by the biotic activity within the CU Soil ® over time as root growth, as cementitious compounds interact with the soil-stone interface within the CU Soil ® bulk system.

'CU SOIL'

STRUCTURAL SOIL

DESCRIPTION AND SPECIFICATION

This is a compilation of information from the author with input and formatting into specification language from various individuals; most notably Dr. Lynne Irwin for the Cornell Local Roads Program, and James Urban and his staff at Urban and Associates, Annapolis, MD.

This section describes the specification and mixing of a gap-graded material targeted to conform to a GP-GM material as defined by the Unified Soil Classification system with a minimum California Bearing Ratio exceeding 50 when properly compacted.

The intent is to form a two phase system: a rigid, high bearing capacity stone structure and a viable rooting zone for planted material suspended within the voids of the stone structure. This is achieved by mixing an angular stone of known size and shape with a soil predominately passing a #200 sieve. The object is to minimize or eliminate all size fractions between 0.75 inches and medium sand (0.16 inches) as defined by the USDA soil classification system.

The material is designed to function as a sub-base material under pavements for pedestrian traffic or light vehicular traffic with the ability to withstand loading of emergency and/or maintenance vehicles. Its intended purpose is for establishing trees in areas where the tree is totally surrounded by pavement and space limitations or other factors preclude the use of non-paved tree zones or large tree planting containerized areas.



1.01 GENERAL

The work of this Section consists of all Structural Soil work and related items as indicated on the Drawings or as specified herein and includes, but is not limited to, the following:

- A. CU Soil ® .

1.02 REFERENCES AND STANDARDS

- A. The following references are used herein and shall mean:
 - 1. ASTM: American Society of Testing Materials.
 - 2. USDA: United States Department of Agriculture.
 - 3. AASHTO: American Association of State Highway and Transportation Officials.
 - 4. Standard Specifications: Regional or Municipal Standard Specifications Documentation for the location of proposed usage.
 - 5. AOAC: Association of Official Agricultural Chemists

1.03 SAMPLES AND SUBMITTALS

- A. At least 30 days prior to ordering materials, the Contractor shall submit to the Engineers representative samples, certificates, manufacturers literature and certified tests for materials specified below. No materials shall be ordered until the required samples, certificates, manufacturers literature and test results have been reviewed and approved by the Engineer. Delivered materials shall closely match the approved samples. Approval shall not constitute final acceptance. The Engineer reserves the right to reject, on or after delivery, any material that does not meet these specifications.
- B. Submit two - one half cubic foot representative samples of Clay Loam and two - two cubic foot representative samples Structural Soil mixes in this section for testing, analysis and approval. Submit one set of samples for every 500 CY of material to be delivered. In the event of multiple source fields for Clay Loam, submit a minimum of one set of samples per source field or stockpile. Samples shall be taken randomly throughout the field or stockpile at locations as directed by the Engineer and packaged in the presence of the Engineer. Contractor shall deliver all samples to testing laboratories and shall have the test results sent directly to the Engineer. Samples shall be labeled to include the location of the source of the material, the date of the sample and the Contractors name. One of the two samples is to be used by the testing laboratory for testing purposes. The second sample of all Clay Loam and Structural Soil shall be submitted to the Engineer at the same time as test analysis as a record of the soil color and texture.



1. Submit the locations of all source fields for Clay Loam.
 2. Submit a list of all chemicals and herbicides applied to the Clay Loam for the last five years and a list of all crops grown in the Clay Loam source fields for the last three years.
- C. Submit soil test analysis reports for each sample of Clay Loam and Structural Soil from an approved soil-testing laboratory. The test results shall report the following:
1. The soil testing laboratory shall be approved by the Engineer. The testing laboratory for particle size and chemical analysis may be a public agricultural extension service agency or agricultural experiment station.
 2. Submit a bulk density of the sample and particle size analysis including the following gradient of mineral content:

USDA Designation	Size in mm.
Gravel	+2mm
Sand	0.05 - 2 mm
Silt	0.0002-0.05 mm
Clay	minus 0.002 mm

Sieve analysis shall be performed and compared to USDA Soil Classification System. Sieve analysis shall be done by a combined hydrometer and wet sieving using sodium hexametaphosphate as a dispersant in compliance with ASTM D422 after destruction of organic matter by hydrogen peroxide.

3. Submit a chemical analysis, performed in accordance with current AOAC Standards, including the following:
 - a. pH and Buffer pH.
 - b. Percent organic matter as determined by the loss of ignition of oven dried samples. Test samples shall be oven dried to a constant weight at a temperature of 230 degrees F, plus or minus 9 degrees.
 - c. Analysis for nutrient levels by parts per million including nitrate nitrogen, ammonium nitrogen, phosphorus, potassium, magnesium, manganese, iron, zinc, calcium and extractable aluminum. Nutrient test shall include the testing laboratory recommendations for supplemental additions to the soil as calculated by the amount of material to be added per volume of soil for the type of plants to be grown in the soil.
 - d. Analysis for levels of toxic elements and compounds including arsenic, boron, cadmium, chromium, copper, lead mercury, molybdenum, nickel, zinc and PCB. Test results shall be cited in milligrams per kilogram.



- e. Soluble salt by electrical conductivity of a 1:2 soil/water sample measured in Millimho per cm.
 - f. Cation Exchange Capacity (CEC).
 - g. Carbon/Nitrogen Ratio.
4. Submit 5-point minimum moisture density curve AASHTO T 99 test results for each Structural Soil sample without removing oversized aggregate.
 5. Submit California Bearing Ratio test results for each Structural Soil sample compacted to peak standard density. The soaked CBR shall equal or exceed a value of 50.
 6. Submit measured dry-weight percentage of stone in the mixture.
 7. The approved Structural Soil samples shall be the standard for each lot of 500 cubic yards of material.
8. All testing and analysis shall be at the expense of the Contractor.
- D. Maintenance Instructions: Prior to the time of Final Acceptance of the Work, submit maintenance instructions for the use, removal and replacement of Structural Soil for the licensor's (Amereq corp.) use. The instructions shall be reviewed by the Project Engineer as a pre-condition for Final Acceptance of the Work.
- E. Submit to the Engineer for review a proposed plan and vertical section layout of all Structural Soil.
- F. Submit one cubic foot sample per each 500 cubic yards of required material, and for each sample, the following analysis for all Crushed Stone. The soil testing laboratory shall be approved by the Engineer.
1. Provide a particle size analysis including the following gradient of mineral content:

USDA Designation	Size in mm.
3@	+76mm
2-1/2@	63-76mm
2@	50-63mm
1-1/2@	37-50mm
1@	25-37mm
3/4@	19-25mm



Fine gravel	2-19mm
Sand	0.05 -2 mm
Silt	0.002-0.05 mm
Clay	minus 0.002 mm

2. Provide the manufacturers analysis of the following:
 - a. Loose and rodded unit weight.
 - b. Bulk specific gravity and absorbency.
 - c. Stone dimension and surface texture description.
 - d. Documentation of acceptance for use as DOT approved aggregate by the appropriate regional DOT.

3. Provide a percent pore space analysis defined as follows:
 $(1 - \text{Rodded Unit Weight} / \text{Bulk Specific Gravity}) \times 100$

- G. Submit one pound sample of each type of fertilizer and 3 certificates showing composition and analysis. Submit the purchasing receipt for each fertilizer showing the total quantity purchased for the project prior to installation.

- H. Submit the Landscape or Pavement Material Contractor's qualifications outlining projects of similar quality, schedule requirements and construction detailing over the last 5 years. Qualifications shall include: The names of all similar projects, year completed, location, description of the scope of work including the types and quantities of planting mix / pavement material installed and the name, address and telephone number of the owner or the owner's representative.

1.04 DELIVERY, STORAGE, AND HANDLING

- A. Do not deliver or place soils in frozen, wet, or muddy conditions. Material shall be delivered at or near optimum compaction moisture content as determined by AASHTO T 99 (ASTM D 698). Do not deliver or place materials in an excessively moist condition (beyond 2 percent above optimum compaction moisture content as determined by AASHTO T 99 (ASTM D 698).

- B. Protect soils and mixes from absorbing excess water and from erosion at all times. Do not store materials unprotected from large rainfall events. Do not allow excess water to enter site prior to compaction. If water



is introduced into the material after grading, allow material to drain or aerate to optimum compaction moisture content.

1.05 EXAMINATION OF CONDITIONS

- A. All areas to receive Structural Soil shall be inspected by the Contractor before starting work and all defects such as incorrect grading, compaction and inadequate drainage etc. shall be reported to the Engineer prior to beginning this work.
- B. The Contractor shall be responsible for judging the full extent of work requirements involved, including but not limited to the potential need for temporary storage and staging of soils, including moving soil stock piles at the site to accommodate scheduling of other work and the need to protect installed soils from compaction, erosion and contamination.

1.06 QUALITY ASSURANCE

- A. Qualifications of Landscape or Pavement Material Contractor: The work of this section shall be performed by a Landscape Contracting firm which has a minimum of 5 years experience successfully installing planting mix of a similar quality, schedule requirement and construction detailing to this project. Proof of this experience shall be submitted as per paragraph, SAMPLES AND SUBMITTALS, of this Section.

MATERIALS

2.01 CLAY LOAM

- A. Clay Loam shall be a “loam” based on the “USDA classification system” as determined by mechanical analysis (ASTM D-422) and it shall be of uniform composition, without admixture of subsoil. It shall be free of stones greater than one-half inch, lumps, plants and their roots, debris and other extraneous matter over one inch in diameter or excess of smaller pieces of the same materials as determined by the Engineer. It shall not contain toxic substances harmful to plant growth. It shall be obtained from naturally well-drained areas, which have never been stripped of top soil before and have a history of satisfactory vegetative growth. Clay Loam shall contain not less than 2% nor more than 5% organic matter as determined by the loss on ignition of oven-dried samples. Test samples shall be oven-dried to a constant weight at a temperature of 230 degrees F., plus or minus 9 degrees.
- B. Mechanical analysis for a Loam / Clay Loam shall be as follows:



Textural Class	% of total weight
Gravel	less than 5%
Sand	20 - 45%
Silt	20 - 50%
Clay	20- 40%

C. Chemical analysis: Meet or be amended to meet the following criteria.

1. pH between 5.5 to 6.5
2. Percent organic matter 2 -5% by dry weight.
3. Nutrient levels as required by the testing laboratory recommendations for the type of plants to be grown in the soil.
4. Toxic elements and compounds below the United States Environmental Protection Agency Standards for Exceptional Quality sludge or local standard; whichever is more stringent.
5. Soluble salt less than 1.0 Millimho per cm.
6. Cation Exchange Capacity (CEC) greater than 10
7. Carbon/Nitrogen Ratio less than 33:1.

D. Clay Loam shall be the product of a commercial processing facility specializing in production of stripped natural topsoil. No topsoil shall come from USDA - classified prime farmland.

2.02 FERTILIZER

- A. Commercial fertilizer complying with State and United States fertilizer laws. Deliver fertilizer in original unopened containers, which shall bear the manufacturer's certificate of compliance covering analysis, which shall be furnished to the Engineer. Fertilizer shall be formulated for mixing into the soil and be certified by the manufacturer to provide controlled release of nitrogen continuously for a period of no less than 9 months and no more than 12 months.
- B. Fertilizer percentages of weight of ingredients and application rates shall be as recommended by the soil testing results.

2.03 SULFUR (if needed)

- A. Sulfur shall be commercial granular, 96% pure sulfur, delivered in containers with the name of the manufacturer, material and analysis appearing in the container.



- B. Sulfur used to lower soil pH above 6.5 shall be ferrous sulfate formulation.

2.04 LIME (if needed)

- A. Agricultural limestone containing a minimum of 85% carbonates. Minimum gradation: 100% passing 10 mesh sieve; 98% passing 20 mesh sieve; 55% passing 60 mesh sieve and 40% passing 100 mesh sieve.

2.05 CRUSHED STONE

- A. Crushed Stone shall be a DOT certified crushed stone. Granite and limestone have been successfully used in this application. Ninety-100 percent of the stone should pass the 1.5 inch sieve, 20-55 percent should pass the 1.0 inch sieve and 10 percent should pass the 0.75 inch sieve. A ratio of nominal maximum to nominal minimum particle size of 2 is required.
- B. Acceptable aggregate dimensions will not exceed 2.5:1.0 for any two dimensions chosen.
- C. Minimum 90 percent with one fractured face, minimum 75 percent with two or more fractured faces.
- D. Results of Aggregate Soundness Loss test shall not exceed 18 percent.
- E. Losses from LA Abrasion tests shall not exceed 40%.

2.06 HYDROGEL

- A. Hydrogel shall be a potassium propenoate-propenamamide copolymer Hydrogel as manufactured by Gelscape by Amereq Corporation. (800) 832-8788

2.07 WATER

- A. The Contractor shall be responsible to furnish his own supply of water to the site at no extra cost. All work injured or damaged due to the lack of water, or the use of too much water, shall be the Contractor's responsibility to correct. Water shall be free from impurities injurious to vegetation.

2.08 STRUCTURAL SOIL

- A. A uniformly blended mixture of Crushed Stone, Clay Loam and Hydrogel, mixed to the following proportion:

MATERIAL	UNIT OF WEIGHT
Crushed Stone	100 units dry weight

Loam	As determined by the test of the mix (Approx. 20 units)
Hydrogel	0.03 units dry weight
Total moisture	AASHTO T-99 optimum moisture)

- B. The initial mix design for testing shall be determined by adjusting the ratio between the Crushed Stone and the Clay loam (see Appendices I and II). Adjust final mix dry weight mixing proportion to decrease soil in mixture if CBR test results fail to meet acceptance (CBR # 50).

CONSTRUCTION METHODS

3.01 MIX DESIGN

- A. Prepare sample Structural Soil mixes to determine the ratio of mix components. Submit for approval.
 - 1. Submit samples and the test results of each mix component for approval. Based on samples and the analysis of the mix components, the Engineer and the Contractor will jointly determine a mix ratio to be tested for conformance with the requirements of the specifications. For Structural Soil quantities greater than 500 cubic yards, test the mix ratio for each Clay Loam or Crushed Stone where the testing indicates a significant difference in physical analysis of the Clay Loam or Crushed Stone as determined by the Engineer.
 - 2. The Contractor shall prepare the samples of the proposed mix ratio options and obtain soil test as described in paragraph 1.04. C. Submit the samples of each of the mixes with the test results.
 - 3. The Engineer may request additional Structural Soil mix ratio samples to be tested in the event that further refinement of the mix is necessary.
 - 4. Submit to the Engineer proposed fertility amendment recommendations including amounts and types of fertilizers and pH adjustments for each mix ratio. Fertility adjustments shall be included as part of the mixing process.

3.02 SOIL MIXING AND QUALITY CONTROL TESTING

- A. All Structural Soil mixing shall be performed at the Contractor’s yard using appropriate soil measuring, mixing and shredding equipment of sufficient capacity and capability to assure proper quality control and



consistent mix ratios. No mixing of Structural Soil at the project site shall be permitted. Portable pugging may be used.

1. Maintain adequate moisture content during the mixing process. Soils and mix components shall easily shred and break down without clumping. Soil clods shall easily break down into a fine crumbly texture. Soils shall not be overly wet or dry. The contractor shall measure and monitor the amount of soil moisture at the mixing site periodically during the mixing process.
 2. A Mixing procedure for front-end loader shall be as follows:
 - a. On a flat asphalt or concrete paved surface, spread an 8 inch to 12 inch layer of crushed stone.
 - b. Spread evenly over the stone the specified amount of dry hydrogel.
 - c. Spread over the dry hydrogel and crushed stone a proportional amount of clay loam according to the mix design.
 - d. Blend the entire amount by turning, using a front-end loader or other suitable equipment until a consistent blend is produced.
 - e. Add moisture gradually and evenly during the blending and turning operation as required to achieve the required moisture content. Delay applications of moisture for 10 minutes prior to successive applications. Once established, mixing should produce a material within 1% of the optimum moisture level for compaction.
 3. A pugging operation mixing procedure may be as follows:
 - a. Feed a known weight of crushed stone into the mixing trough.
 - b. Add hydrogel as a slurry into trough and mix slurry and stone into a uniform blend.
 - c. Meter in soil in proper proportion of Clay loam Soil. While stone-slurry mixture is in motion.
 - d. Add water to bring mixture to target moisture content after factoring in water from the slurry and the Clay-loam moisture.
 - e. Auger out to stock pile or transport vehicle (or into pit if using a portable pugging operation).
 4. Add soil amendments to alter soil fertility including fertilizers and pH adjustment at the time of mixing at the rates recommended by the soil test.
 - a. Soil pH shall be adjusted to fall within a value of 5.5 and 6.5 two months after mixing if the material is stored, unless mixing with a high pH stone. Once pavement is laid, no adjustment should be imposed.
 - b. Soil component Carbon / nitrogen ratio shall be adjusted to be less than 33:1 within two months after mixing.
- B. The Contractor shall mix sufficient material in advance of the time needed at the job site to allow adequate time for final quality control testing as required by the progress of the work. Structural Soil shall be stored in piles of



approximately 500 cubic yards and each pile shall be numbered for identification and quality control purposes. Storage piles shall be protected from rain and erosion by covering with plastic sheeting.

- C. During the mixing process, the Contractor shall take two - one cubic foot quality control samples per 500 cubic yards of production from the final Structural Soil. The samples shall be taken from random locations in the numbered stockpiles as required by paragraph 1.03.B of this specification. Each sample shall be tested for particle size analysis and chemical analysis as described in Paragraph 1.03. C.2 and 3 above. Submit the results directly to the Engineer for review and approval.
- D. The quality control sample Clay Loam-Crushed Stone ratio's shall be no greater or less than 2% of the approved test sample as determined by splitting a known weight of oven dried material on a #4 sieve. In the event that the quality control samples vary significantly from the approved Structural Soil sample, as determined by the Engineer, remix and retest any lot of soil that fails to meet the correct analysis making adjustments to the mixing ratios and procedures to achieve the approved consistency.

3.03 UNDERGROUND UTILITIES AND SUBSURFACE CONDITIONS

- A. Notify the Engineer of any subsurface conditions which will effect the Contractor's ability to complete the work.
- B. Locate and confirm the location of all underground utility lines and structures prior to the start of any excavation.
- C. Repair any underground utilities or foundations damaged by the Contractor during the progress of this work. The cost of all repairs shall be at the Contractor's expense.

3.04 SITE PREPARATION

- A. Do not proceed with the installation of the Structural Soil material until all walls, curb footings and utility work in the area have been installed. For site elements dependent on Structural Soil for foundation support, postpone installation until immediately after the installation of Structural Soil.
- B. Install subsurface drain lines as shown on the Drawings prior to installation of Structural Soil material.



- C. Excavate and compact the proposed sub-grade to depths, slopes and widths as shown on the Drawings. Maintain all required angles of repose of the adjacent materials as shown on the drawings. Do not over excavate compacted sub-grades of adjacent pavement or structures.
- D. Confirm that the sub-grade is at the proper elevation and compacted as required. Sub-grade elevations shall slope parallel to the finished grade and or toward the subsurface drain lines as shown on the drawings.
- E. Clear the excavation of all construction debris, trash, rubble and any foreign material. In the event that fuels, oils, concrete washout silts or other material harmful to plants have been spilled into the sub-grade material, excavate the soil sufficiently to remove the harmful material. Fill any over excavation with approved fill and compact to the required sub-grade compaction.
- F. Do not proceed with the installation of Structural Soil until all utility work in the area has been installed. All subsurface drainage systems shall be operational prior to installation of Structural Soils.
- G. Protect adjacent walls, walks and utilities from damage or staining by the soil. Use 1/2" plywood and or plastic sheeting as directed to cover existing concrete, metal and masonry work and other items as directed during the progress of the work.
 - 1. Clean up all trash and any soil or dirt spilled on any paved surface at the end of each working day.
 - 2. Any damage to the paving or architectural work caused by the soils installation Contractor shall be repaired by the general Contractor at the soils installation Contractor's expense.
- H. Maintain all silt and sediment control devices required by applicable regulations. Provide adequate methods to assure that trucks and other equipment do not track soil from the site onto adjacent property and the public right of way.

3.05 INSTALLATION OF STRUCTURAL SOIL MATERIAL

- A. Install Structural Soil in 6 inch lifts and compact each lift.
- B. Compact all materials to peak dry density from a standard AASHTO compaction curve (AASHTO T 99). No compaction shall occur when moisture content exceeds maximum as listed herein. Delay compaction 24 hours if moisture content exceeds maximum allowable and protect Structural Soil during delays in compaction with plastic or plywood as directed by



the Engineer.

- C. Bring Structural Soils to finished grades as shown on the Drawings. Immediately protect the Structural Soil material from contamination by toxic materials, trash, debris, water containing cement, clay, silt or materials that will alter the particle size distribution of the mix with plastic or plywood as directed by the Engineer.
- D. The Engineer may periodically check the material being delivered and installed at the site for color and texture consistency with the approved sample provided by the Contractor as part of the submittal for Structural Soil. In the event that the installed material varies significantly from the approved sample, the Engineer may request that the Contractor test the installed Structural Soil. Any soil which varies significantly from the approved testing results, as determined by the Engineer, shall be removed and new Structural Soil installed that meets these specifications.

3.06 FINE GRADING

- A. After the initial placement and rough grading of the Structural Soil but prior to the start of fine grading, the Contractor shall request review of the rough grading by the Engineer. The Contractor shall set sufficient grade stakes for checking the finished grades.
- B. Adjust the finish grades to meet field conditions as directed.
 - 1. Provide smooth transitions between slopes of different gradients and direction.
 - 2. Fill all dips and remove any bumps in the overall plane of the slope.
 - a. The tolerance for dips and bumps in Structural Soil areas shall be a 3" deviation from the plane in 10'.
 - 3. All fine grading shall be inspected and approved by the Engineer prior to the installation of other items to be placed on the Structural Soil.
- C. The Engineer will inspect the work upon the request of the Contractor. Request for inspection shall be received by the Engineer at least 10 days before the anticipated date of inspection.

3.07 ACCEPTANCE STANDARDS

- A. The Engineer will inspect the work upon the request of the Contractor. Request for inspection shall be received by the Engineer at least 10



days before the anticipated date of inspection.

3.08 CLEAN-UP

- A. Upon completion of the Structural Soil installation operations, clean areas within the contract limits. Remove all excess fills, soils and mix stockpiles and legally dispose of all waste materials, trash and debris. Remove all tools and equipment and provide a clean, clear site. Sweep, do not wash, all paving and other exposed surfaces of dirt and mud until the paving has been installed over the Structural Soil material. Do no washing until finished materials covering Structural Soil material are in place.



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Urban Forest Guidelines