CITY OF DALLAS, TEXAS
TURTLE CREEK PARK
TREE RESOURCE ANALYSIS

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Executive Summary

The City of Dallas is a large sprawling urban landscape that covers approximately, 385 mi^2 and has over 1.2 million residents. Managing the community tree resource in such a large area can be both costly and challenging. The City of Dallas does employ a City Forester which is charged with the responsibility of all public tree issues, including conducting training for all city departments, plan review and design, and the coordination of volunteers and civic groups who do everything from planting trees to trail building in the Trinity Forest. The understanding of the importance of trees, the benefits that they provide to the citizens of the community, and how formal management may maximize those inherent functional benefits to Dallas residents is growing. In fact, in the summer of 2008 the Turtle Creek Association, a non-profit group made up of Dallas residents who live and/or work in and around the well known Turtle Creek Greenbelt Park, contracted to have a professional tree survey performed in order to better understand their community tree resource. A survey on all trees 4" and greater was conducted within both managed and unmanaged/natural areas of the park. The data was then provided to the Texas Forest Service in the fall of 2009 for an analysis, utilizing the i-Tree Streets Program (formerly called STRATUM), that would focus on four main areas:

1. Tree resource structure (species composition, diversity, age distribution, condition, etc.)
2. Tree resource function (magnitude of environmental and aesthetic benefits)
3. Tree resource value (dollar value of benefits realized)
4. Tree resource management needs (sustainability, maintenance, costs)

Effectively, the primary question to be asked is whether the benefits received outweigh the annual expenditures? In this case, the urban forest resource is owned and operated by the City of Dallas. Unfortunately, there was no management cost data available for this specific site so all benefit values are reported as gross values only, rather than net values. Therefore, a benefit cost analysis was not possible. Still, the values related to the benefits produced by the community forest provide a baseline of data to help promote the proper care of this resource as well as make some general management recommendations possible.

<u>Resource Structure</u>

- Based on a preexisting tree inventory of all trees 4" or greater in the linear park, there are 2,602 trees in the Turtle Creek Greenbelt.
- The tree canopy for the greenbelt is estimated at 41 acres and covers 46% of the Park.
- The survey demonstrates that there are 45 tree species with American elm and sugarberry as the dominant trees, each accounting for 15% of the total population. While the elms provide 22% of all the benefits, sugarberry only contributes 8%. This means that sustaining the high level of benefits currently produced by the municipal forest depends largely on preserving these elms. Additionally, while pecan only represents 9% of the total population, they provide 14% of the total benefits due to their large size. However, eastern red cedar (9%), tree of heaven (8%), Shumard red oak (8%), cedar elm (6%), green ash (4%), red mulberry (3%), and chinaberry (3%) are subdominant species of importance due to their size and numbers.
- The average tree diameter is 12"

• The age structure of Turtle Creek Park's trees differs from the ideal in having more maturing trees (6–18 inch DBH) and fewer mature and old trees. In fact, over 68% of all trees fall within the 6-18" diameter range. As these maturing trees age, the benefits they produce will increase. Thus, over the next 50 years, their health and longevity will influence the stability and productivity of the population's future canopy.

⬬Trees are generally in good health, with approximately 2% of the population found dead and only 1% with significant insect, fungus, and/or bacterial-related stress concerns.

⬬7.2% (188) require some level of pruning, 0.5% (12) requires cabling/bracing, and 1.2% (31) of all trees may require removal.

Resource Function and Value

⬬The Replacement value of the 2,602 surveyed trees is $9.2 million

⬬First-order estimates of electricity savings attributed to the park trees from both shading and climate effects totals 206 MWh, for a retail savings of $15,643 ($6.01 per tree). Total annual savings of natural gas total 7,660 MBtu, for a savings of $8,012 or $3.08 per tree. Total annual energy savings are valued at $23,655 or $9.09 per tree.

⬬Annual CO_2 emission reductions due to sequestration and energy savings by trees are 448 tons and 87 tons valued at $6,719 ($2.58 per, tree) and $1,248 ($0.50 per tree), respectively. Release of CO_2 from decomposition and tree-care activities is estimated at 17.6 tons valued at -$264 annually. Net CO_2 reduction is 517 tons, valued at $7,761 or $2.98 per tree.

⬬Net air pollutants removed, released, and avoided totaled 17.4 lbs with an average of .007 lb per tree and are valued at $-5,693 annually or $-2.19 per tree. Avoided emissions of NO_2 and SO_2 due to energy savings are especially important, totaling 1,372 lbs or 89% of all avoided pollution. Annual deposition and interception of pollutants by all trees totaled 948 lbs valued at $4,370, an important benefit in a region with an EPA clean air non-attainment status. However, the overall negative net value is related to biogenic volatile organic compounds (BVOC) naturally released into the air by certain tree species. The total for BVOC released is 1.2 tons annually with a value of -$15,461. The three tree species with the highest total release of BVOC are American elm, pecan, and Shumard oak. However, the species with the lowest per tree value are bur oak, post oak, and Eastern cottonwood with -$8.62, -$11.35, and -$22.71, respectively.

⬬The ability of Turtle Creek's trees to intercept rain—thereby reducing stormwater runoff is substantial, at an estimated 6.7 million gallons (894,239 cubic feet) annually, or $66,229. Each year the average tree intercepts approximately 2,571 gallons of stormwater, valued at $25.45, annually.

⬬The estimated annual benefits associated with aesthetics, property value increases, and other less tangible benefits are approximately $115,194 or $44 per tree.

⬬Total annual gross benefits are $207,146 and average $79.61 per tree. Aesthetics benefits account for over half of all benefits received with 56%. Stormwater-runoff reduction, energy savings, and CO_2 reduction benefits provide 32%, 11%, and 4%, respectively. The tree species providing the greatest benefits across all benefit categories on a per tree basis are eastern cottonwoods ($195 per tree), post oaks ($150 per tree), and live oaks ($128 per tree). However, the tree species providing the greatest percentage of benefits based on the total produced annually are American elm (20%), pecan (13%), and Shumard red oak (11%) because of their size and/or numbers.

• A benefit-cost analysis was not performed at this time since management costs were not available. However, the benefits realized from the existing trees will increase with increased formal management that promotes the forest's overall health and growth. As the urban forest resource grows, the city should continue to invest in formal management activities that promote a positive return on the community's investment in the future.

Resource Management Needs

Dallas's municipal trees are wide spread and diverse. For this reason they provide both environmental and social benefits which improve the quality of life for the citizens. However, in order to maximize and sustain these benefits into the future a sustained and professional management program must be established. Management on the trees within Turtle Creek's managed areas should focus on the following:

- Continued investment in the formal management of the tree resource including staff specifically charged with the care of all public trees including street and park trees.
- Utilize the HALFF data to locate dead, dying, and diseased trees that may require removal
- Establish an immediate pruning program on trees within the 6-18" diameter class that exist within the managed areas of the park since these individuals will become the main canopy of the park in the future and thus, will provide the majority of benefits.
- Reduce future long-term tree-care costs by establishing a young tree care policy to insure that these trees will be productive assets for the community in the future.
- Continue to provide adequate diversity through systematic, planned tree planting including planting large-stature tree species where space permits.

As Turtle Creek's urban forest canopy continues to mature, so should the realized public benefits from this important public resource. However, given the current economic downturn and trends toward reduced proactive management the potential benefits may be compromised. It will be important to foster the health and productivity of this important resource amid ever decreasing public budgets. However, the pivotal goal must be to continue to enhance the tree canopy coverage by utilizing available planting space for new trees and replacing over-mature trees in order to maximize net benefits into the future. Ultimately, efforts should be designed at creating a resource that is both functional and sustainable.

Chapter One—Introduction

The approximately 90 acre Turtle Creek Park, a city owned and maintained public greenbelt along Turtle Creek Blvd. is situated just north of downtown Dallas, Texas and is bordered by Oaklawn Ave to the North, Cole Ave. to the South, Maple Ave. to the West, and N. Fitzhugh Ave. to the East (Figure 1). While the city does manage the park, no formal inventory on the park's trees had previously been completed. In the summer of 2008 the Turtle Creek Association, a non-profit group made up of Dallas residents who live and/or work in and around the well known Turtle Creek Greenbelt Park, contracted HALFF Associates, Inc. to perform a professional tree survey in order to better understand their community tree resource. The data was then provided to the Texas Forest Service in the fall of 2009 for an analysis of the environmental benefits that the park's trees provide to the public. The i-Tree Streets Program (formerly called STRATUM) was utilized in this analysis. The program is based on growth models of regionally predominant species within a "reference city", which serves as a representative community for other cities within the region. The city of Charlotte, North Carolina serves as the reference city for the DFW area (McPherson et al. 2006). While this program was originally designed to assess street trees or trees that are growing along the right-of-way (ROW), front yards, and medians it was determined that due to the narrowness of the Turtle Creek greenbelt, its heavily urbanized surroundings, and since many of the trees within the park follow the street corridors and border paved surfaces that the program serves as a practical analysis tool. The goal of this report is to demonstrate the value of the community forest resource based on the structural information provided by the HALFF survey. This information may also support the need for improved forest health, the importance of proactive management, and strategies for long-term resource planning. Finally, the development of strong partnerships between the community and city leaders is also encouraged.

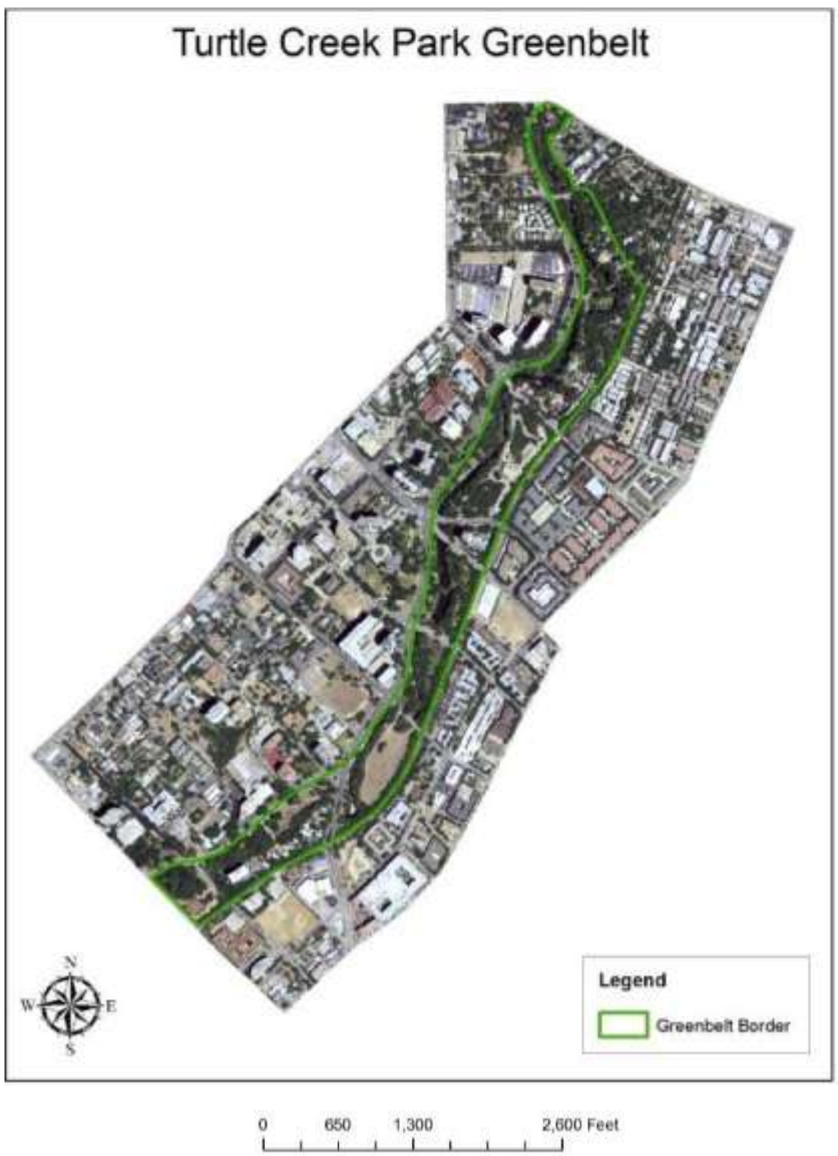
While a real cost exists to the public in managing the urban forest resource, the environmental and social benefits received from the resource most often greatly outweigh the costs of management. Furthermore, proactive management commonly reduces long-term costs by producing higher quality and healthier trees, which require less maintenance and more benefits over time. An increased investment in formalized tree management will help enhance the livability for Dallas residents. Research has shown that healthy city trees can be one of many tools that help address the negative impacts associated with urban environments such as polluted stormwater runoff, poor air quality, high energy needs for heating and cooling buildings, and heat islands. In addition, healthy urban trees have important socioeconomic benefits that can positively affect real estate values, help to define communities, and have a calming psychological effect on resident health. There are also less quantifiable benefits such as increased aesthetics and benefits for wildlife.

Turtle Creek's trees are a small component of Dallas' entire urban forest which contributes to the overall quality of life for its residents by providing both social and environmental benefits. Unfortunately, in an environment of shrinking public funds and rising costs urban forestry budgets are commonly identified for cuts. The City of Dallas Parks and Recreation Department has recently experienced major budgetary cut-backs which may reduce its capacity to effectively manage the public component of the urban forest in Dallas. One primary question that should be asked is whether the accrued benefits from Dallas's public trees justify the annual expenditures? Unfortunately, no benefit cost analysis was done at this time. This report's focus is on a single public park to illustrate the relationship between public trees and the benefits they provide.

This report consists of five chapters and three appendices:

Chapter One—Introduction: Describes purpose of the study.
Chapter Two— Structure of Dallas's Turtle Creek Tree Resource: Tree types and sizes.
Chapter Three— Benefits of Dallas's Turtle Creek Park Trees: Estimated value of public benefits.
Chapter Four—Management Implications: Evaluates analysis and describes management challenges.
Chapter Five—Conclusion: Summation of analysis.
Appendix A— Tree Population Summary Table
Appendix B— iTree Streets Program Acknowledgments and Methodology.
Appendix C— STRATUM Regional Climate Zones Map.
References—Lists publications cited in the study.

Figure 1: Image of Turtle Creek Park with the boundary outlined.



Chapter Two— Structure of Dallas's Turtle Creek Tree Resource

<u>Tree Numbers</u>

Based on a the 2008 inventory of all Turtle Creek Park trees greater than 4" in diameter conducted by HALFF Associates, Inc. there are 2,602 trees within the city's greenbelt park. This data represents trees located both within the city's right-of-ways along the streets and within the interior of the park in both maintained and unmaintained natural areas (Figure 2). The majority of the trees inventoried are within the broadleaf deciduous tree type with approximately 88%. Furthermore, the population is primarily composed of large and medium trees (>40 ft tall and 25–40 ft tall at maturity) (63 and 33% of the total, respectively) (Table 1).

Figure 2: Maintained and Unmaintained areas of Turtle Creek Park.

Table 1: Tree percentages by size class and tree type

Tree Type	Large	Medium	Small	Total
Broadleaf Deciduous	61.4%	24.1%	2.2%	87.7%
Broadleaf Evergreen	1.5%	0.2%	1.5%	3.2%
Conifer	0.2%	8.9%	0.0%	9.1%
Total	63.1%	33.2%	3.7%	100.0%

Species Richness, Composition and Diversity

The inventory of 2,602 individual trees is comprised of 45 different tree species. Other studies of larger scale found that cities had on average 53 different species (McPherson and Rowntree, 1989). A recent study in Arlington demonstrated a total of 77 different species while a regional study in the Houston area had 67 species. The population summary depicts a stand dominated by large and medium size deciduous trees within the 6-18" diameter classes, specifically American elm (*Ulmus americana*), sugarberry (*Celtis laevigata*), pecan (*Carya illinoensis)*, tree of heaven (*Ailanthus altissima*), and Shumard oak (*Quercus shumardii*) (Appendix A). However, both American elm and sugarberry exceed the general rule that no single species should represent more than 10% of the population (Clark et al. 1997) (Figure 3 and Table 2). Furthermore, tree-of-heaven and chinaberry (*Melia azedarach*), two of the top ten most populous species, are identified as invasive exotic species, which are much less desirable from an ecosystem health perspective.

Figure 3: Top 10 most populous species as percent of total population.

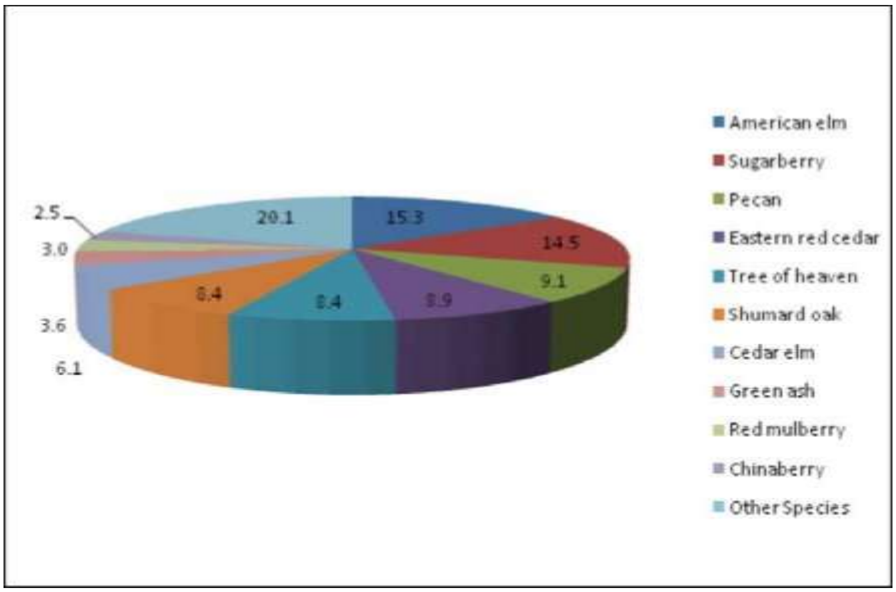


Table 2: Top 10 species as percent of total population

Species	Percent
American elm	15.3
Sugarberry	14.5
Pecan	9.1
Eastern red cedar	8.9
Tree of heaven	8.4
Shumard oak	8.4
Cedar elm	6.1
Green ash	3.6
Red mulberry	3.0
Chinaberry	2.5
Other Species	20.1
Total	100.0

Species Importance

The importance value (IV) of each species, a mean of the three relative values for % of the total number of trees, the % canopy cover, and % leaf area, indicates a community's reliance on the functional capacity of particular species and provides a useful comparison to the total population distribution. The values can range between 0 and 100, where an IV of 100 implies total reliance on one species and an IV of 0 suggests no reliance. The IV can be a useful tool to the forest manager in determining which species play a vital role in the forest.

The 20 most abundant tree species listed in Table 3 constitute 95% of the total population, 94% of the total leaf area, 94% of total canopy cover, and 94% of total IV. Table 3 illustrates that some species are more important than their population numbers suggest. For example, Shumard oak accounts for only 8% of all trees, but has an importance value of 10 as a function of its relative leaf area and canopy cover, making it the 6th most populous tree and the 4th most important. Cedar elm (*Ulmus crassifolia*) is another good example of how a species may have fewer individuals in the population yet be of greater importance to the community forest overall; in this case, the relatively higher IV is related to the species' leaf area value. Conversely, species such as Eastern red cedar (*Juniperus virginiana*) are less important to the community than their numbers alone suggest. While eastern red cedar is the 4th most populous tree species it ranks only 7th in terms of its IV.

Table 3: Importance Value (IV) calculated as the mean of tree numbers, leaf area, and canopy cover of the most prevalent species

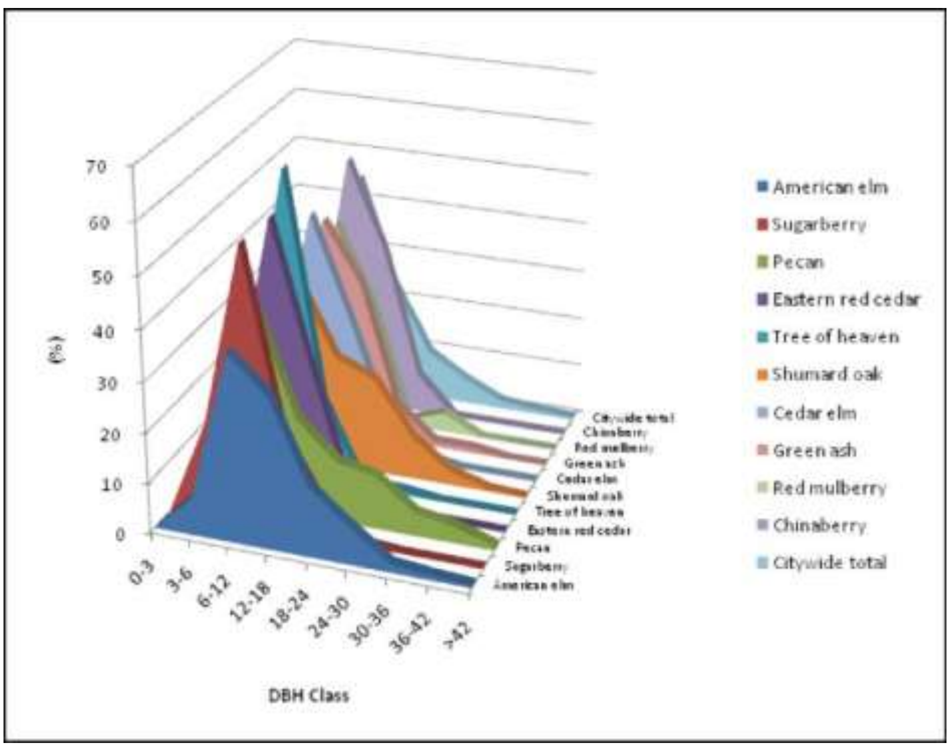
Species	Number of Trees	% of Total Trees	Leaf Area (ft^2)	% of Total Leaf Area	Canopy Cover (ft^2)	% of Total Canopy Cover	Importance Value
American elm	398	15.3	1,545,519	20.9	311,186	17.6	17.9
Sugarberry	378	14.5	556,010	7.5	239,591	13.6	11.9
Pecan	237	9.1	1,185,546	16.0	214,222	12.1	12.4
Eastern red cedar	232	8.9	106,938	1.4	75,874	4.3	4.9
Tree of heaven	219	8.4	292,190	3.9	84,604	4.8	5.7
Shumard oak	219	8.4	876,123	11.8	175,664	10.0	10.1
Cedar elm	159	6.1	334,168	4.5	83,140	4.7	5.1
Green ash	94	3.6	216,177	2.9	51,879	2.9	3.2
Red mulberry	77	3.0	136,896	1.8	34,715	2.0	2.3
Chinaberry	65	2.5	117,898	1.6	47,627	2.7	2.3
Chittamwood	54	2.1	59,136	0.8	30,086	1.7	1.5
Baldcypress	49	1.9	200,967	2.7	40,682	2.3	2.3
Carolina laurelcherry	39	1.5	2,959	0.0	5,871	0.3	0.6
Boxelder	38	1.5	66,477	0.9	25,698	1.5	1.3
Post oak	38	1.5	283,472	3.8	49,961	2.8	2.7
Live oak	38	1.5	223,697	3.0	40,681	2.3	2.3
Eastern cottonwood	34	1.3	453,122	6.1	65,716	3.7	3.7
Bur oak	34	1.3	196,891	2.7	35,805	2.0	2.0
Common crapemyrtle	32	1.2	17,593	0.2	16,220	0.9	0.8
Black willow	31	1.2	90,995	1.2	27,914	1.6	1.3
Other trees	137	5.3	444,632	6.0	107,344	6.1	5.8
Total	2,602	100.0	7,407,404	100.0	1,764,480	100.0	100.0

Certainly, American elm has great functional importance in Dallas's Turtle Creek Park. However, because of its susceptibility to Dutch elm disease (DED) (*Ceratocystis ulmi*) its continued status may become vulnerable, as the disease pushes its way south from the northern states. As recent as 2009, there have been isolated cases of DED reported in the City of Flower Mound in north Tarrant County.

Age Structure

Age diversity is another important factor in the structure of a forest because it is often directly correlated with tree size as are the benefits trees provide. The age distribution can also affect both present and future costs. For example, an uneven-aged population allows managers to allocate annual maintenance costs more uniformly in order to provide a more sustained tree-canopy cover. Thus, an ideal distribution has a high proportion of new transplants to offset establishment-related mortality, while the percentage of older trees declines with age (Richards 1982/83). The age structure for Turtle Creek Trees differs from the ideal in that there are more maturing trees in the 6–18 inch DBH classes, and fewer mature and old trees (Figure 4). This trend may be attributed to development in the area removing many naturally occurring trees. The relatively small number of trees in the mature (18–24 inch DBH) and old tree categories (>24 inch) suggests that relatively few trees survived the era of transition between urban development and park designation. The lack of more mature trees is important because they tend to produce the highest level of benefits by virtue of their size (i.e. leaf surface area). Over time, if maturing trees move into the larger size classes without significant losses, the population will more closely align with the ideal.

Figure 4: Age structure of trees in Turtle Creek Park demonstrates a lack of mature (18-24" DBH) and old (>24" DBH) trees.



The age distribution for the most commonly occurring tree species illustrates their relative importance within the overall population and help with tree management planning into the future (Table 4). The populations of American elm, pecan, and Shumard oak are largely mature. These trees have provided benefits over a longer period of time than trees of other species within the same stand, and because of their leaf area, remain particularly important. The population of sugarberry, eastern red cedar, tree of heaven, cedar elm, green ash (*Fraxinus pennsylvanica*), and red mulberry (*Morus rubra*) include a much higher percentage of young trees, indicating their more recent establishment. Unfortunately, since the original inventory only included individual trees 4" or greater in diameter population/age trends cannot be determined for trees that may have been planted or that have established in the last 10 years. This is very important because the above species that represent the younger cohort (smaller diameter classes) are mostly represented by medium size tree species. Since larger trees provide more benefits there will be fewer large species of trees maturing over the next couple of decades, thus limiting the overall public benefits in the future.

Table 4: Age distribution as a percent of occurrence in each diameter class for the ten most populous species in Turtle Creek

	DBH class (in)								
Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42
American elm	0.00	7.79	37.19	30.40	13.82	7.54	1.76	1.01	0.50
Sugarberry	0.00	19.05	54.76	19.31	6.35	0.53	0.00	0.00	0.00
Pecan	0.00	9.70	39.24	19.41	12.24	10.55	4.64	3.38	0.84
Eastern red cedar	0.00	14.22	54.31	27.16	2.59	1.72	0.00	0.00	0.00
Tree of heaven	0.00	20.55	61.19	16.44	0.91	0.91	0.00	0.00	0.00
Shumard oak	0.00	10.05	36.53	22.37	19.18	8.68	2.74	0.46	0.00
Cedar elm	0.00	15.09	47.17	28.30	8.18	1.26	0.00	0.00	0.00
Green ash	0.00	14.89	43.62	31.91	7.45	1.06	1.06	0.00	0.00
Red mulberry	0.00	29.87	40.26	24.68	1.30	3.90	0.00	0.00	0.00
Chinaberry	0.00	7.69	50.77	33.85	7.69	0.00	0.00	0.00	0.00
Citywide total	0.00	14.07	44.93	23.25	9.76	5.11	1.58	0.85	0.46

Tree Condition

Tree condition indicates both how well trees are managed and how well they perform given site-specific conditions. Overall, 2% (64) of all trees inventoried are dead, 4% (94) may be classified as being in "poor" condition, 65% (1700) as "fair", 23% (607) as "good", and 5% (137) are rated as being in "excellent" condition based on their crown development (Table 5). Furthermore, it was noted that 1% (20) has some level of insect, fungus, or bacterial-related damage.

Table 5: Tree Conditions for Turtle Creek

Excellent	137	5%
Good	607	23%
Fair	1700	65%
Poor	94	4%
Dead	64	2%
	2602	100%

Tree Canopy

The tree canopy for the greenbelt is estimated at 41 acres and covers 46% of the surface area of Turtle Creek, given an area of 88 acres as measured with geographical information system (GIS) data utilizing 1 meter resolution leaf-on imagery from the National Agricultural Imagery Program (NAIP) collected in summer 2008. Recent canopy cover percentages (city wide including both public and private trees) from the cities of Arlington and San Antonio found canopy coverage of 22% and 38%, respectively, while the Houston regional study showed a 28% canopy cover. With more than fifty percent of the total land surface area of the park covered by tree canopy the Turtle Creek community receives a great deal of benefits from this resource. Management strategies designed to promote this canopy should be focused on the species with the highest benefit values (as described in the next section) and should be a priority in order to maximize benefit potential into the future.

Maintenance Needs

Understanding species distribution, age structure, and tree condition can be helpful for determining proper pruning cycles, however, the actual pruning needs of the trees as noted during a tree survey is crucial. This information can assist the municipal forest manager in determining an adequate pruning cycle that favors both tree growth and structure and can also help to assess the level of risk and liability associated with the city's tree population. An assessment of maintenance needs showed that approximately 10% of the trees are in need of some form of maintenance (Table 6). To promote continued good health and performance, 7.2% (188) of the trees need some form of pruning, 1.2% (31) of the population needs to be inspected for possible removal, 0.5% (12) require cabling or bracing to secure defective branches/trunks, and 0.8% (21) require removal of soil at base of the trunk in order to expose the root collar and improve oxygen transfer between the roots and the atmosphere.

Table 6: Maintenance needs for Turtle Creek trees as a percent of total trees

Category	Number	Percent
None	2350	90.3%
Cabling/Bracing	12	0.5%
Pruning	188	7.2%
Potential Removal	31	1.2%
Root Collar Exposure	21	0.8%
Total	2602	100%

Trees classified as potential removals tend to have severe problems. Although not all may be public safety concerns these individuals should be revisited according to the HALFF survey locations and removal should be prioritized according to known species limitations such as expected life span, wood strength/quality, and use frequency of the site in question. Damaged and/or diseased trees are also less aesthetically pleasing. Data in Table 6 can be used with tree-care cost estimates to calculate the amount of funding required to address current management needs and should focus on highly visited managed areas within the park to minimize liability.

Chapter Three— Benefits of Dallas's Turtle Creek Park Trees

Introduction

The public trees in any community are constant civil servants. That is that they continually work for the public by providing both social and environmental benefits. Benefits such as air quality improvement through the reduction of pollutants, stormwater management savings through the crowns' and roots' ability to slow down and absorb rain water, effectively reducing the number of gallons a city must control, energy saving benefits though the ability to reduce ambient air temperatures and the cooling affect on homes by shading which reduces the use of air conditioning and the release of CO_2, and finally trees also absorb and store carbon dioxide which in turn, when limited, has a positive effect on both temperature and air quality. Trees also provide a valuable aesthetic which has been shown to improve real estate sales and commercial/retail spending in well forested areas. These ecosystem services and socioeconomic benefits directly improve human health and quality of life. Therefore, it is important that these real benefits and their attributed values be described.

Not all benefits can be clearly and completely addressed however due to fact that some benefits are difficult to quantify (e.g., impacts on psychological health, crime, and violence). Also, the lack of understanding of more complex relationships between some variables such as air pollution, trees, and rain create some level of imprecision inherent in the model estimates. Species-specific tree growth and mortality rates are also highly variable and should be further investigated for the local area. Therefore, these estimates provide first-order approximations that indicate tree value. This chapter provides a detailed look at the various benefit categories and the estimated values produced by the trees in Turtle Creek. These data should be used conservatively as a baseline from which management decisions can be made (Maco and McPherson 2003). Research and methodology used to quantify and price these benefits are described in more detail in Appendix B.

Finally, it must be stated that a discussion of benefits is best accompanied with an accounting of the management costs involved in the care of the tree resource. Maintenance categories such as Pruning, Planting, Removal & Disposal, Inspections, Irrigation, Litter, Clean-Up, Liability & Legal, Infrastructure Repairs/Mitigation, and Administration & Other are common cost factors related to most formal urban forestry programs and municipal governments can improve their effectiveness when they fully consider and track these expenses. Unfortunately, no cost data was available at the time of this report. Cost data will enable a benefit-cost analysis in order for the city to determine what the estimated return on the investment of management is. Therefore, the values presented here are gross annual estimates of the benefits that the trees of Turtle Creek Park rather than net benefits.

Replacement Value

Replacement values are estimates of the full cost of replacing trees in their current condition, should they be removed for some reason. Species ratings, replacement costs, and basic prices were obtained for each species according to the regional appraisal guide for the reference city (McPherson et al. 2006). Because of the approximations used in these calculations, replacement values are first-order estimates for the population and are not intended to be definitive on a tree-by-tree basis. The 2,602 trees within the Turtle Creek Greenbelt have an estimated replacement value of $9.2 million.

Energy Savings

Over many decades there has been an effort to more clearly understand how trees impact our urban/suburban environment with respect to temperature and energy use and savings. Some studies have focused on small scale interactions between trees and temperature, where trees and other vegetation directly within building sites were shown to lower air temperatures by as much as 5°F (3°C) compared to outside the greenspace (Chandler 1965). Other research has focused on the interaction at the larger scale of urban climate (6 mi^2 or 10 km^2); illustrating that temperature difference of more than 9°F (5°C) between city centers and the more vegetated suburban areas are possible (Akbari et al. 1992). Finally, others have focused on the influence tree type, shape, size, and arrangement across the landscape can have on air temperature and the movement of pollutants (McPherson 1993). Thus, forest structural parameters such as tree spacing, crown spread, and vertical distribution of leaf area may in fact influence the transport of warm air and pollutants throughout the urban landscape.

Ultimately, trees modify climate and conserve energy in three principal ways:

1. Through shading of built surfaces and effectively reducing the amount of radiant energy absorbed and stored and later released into the air.
2. Through the process of transpiration, or the release of water vapor from leaf surfaces, that cools the air by using solar energy that would otherwise result in heating of the air.
3. Through the reduction of the movement of outside air into interior spaces and conductive heat loss where thermal conductivity is relatively high (e.g., glass windows) (Simpson 1998).

Electricity and Natural Gas Results

The energy benefits from trees are derived from a model that originally focused on street trees, or trees in the public rights-of-way. The model assumes trees impact energy use in two ways: from the shading (cooling) of homes and climate effects (transpirational cooling of ambient air). In this study while many trees bordered street corridors and paved surfaces, relatively few trees directly impacted residential home sites and thus the energy benefits should be viewed conservatively. However, a lower energy cost rate of $0.076 per Kwh instead of the local average of $0.12 Kwh was used to produce a more conservative estimate.

Electricity saved annually as a result of the Turtle Creek tree population (Table 7) totals 206.1 MWh, for a retail savings of $15,643 ($6.01 per tree). Total annual savings of natural gas total 7,659.7 MBtu, for a savings of $8,012 ($3.08 per tree). Net energy savings are split: 34% winter heating and 66% summer air conditioning. Total citywide savings are valued at $23,655. Average savings per tree are $9.09. The species producing the greatest annual energy benefits as a percentage of total benefits are American elm (18%), sugarberry (14%), and pecan (12%). Several species exceeded the average savings benefits on a per-tree basis due to their large size and included Eastern cottonwood ($23 per tree), post oak ($17), bur oak ($14), and live oak ($13).

Table 7: Cooling, heating, and gross annual energy savings produced by predominant tree species.

Species	Total Electricity (MWh)	Electricity ($)	Total Natural Gas (Therms)	Natural Gas ($)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
American elm	36.9	2,801	1,370.8	1,434	4,235	(N/A)	15.3	17.9	10.64
Sugarberry	27.3	2,074	1,096.9	1,147	3,222	(N/A)	14.5	13.6	8.52
Pecan	24.9	1,890	876.2	916	2,806	(N/A)	9.1	11.9	11.84
Eastern red cedar	9.0	682	233.2	244	926	(N/A)	8.9	3.9	3.99
Tree of heaven	10.2	774	435.1	455	1,229	(N/A)	8.4	5.2	5.61
Shumard oak	20.6	1,565	769.1	804	2,369	(N/A)	8.4	10.0	10.82
Cedar elm	10.1	764	406.9	426	1,190	(N/A)	6.1	5.0	7.48
Green ash	6.3	477	250.1	262	738	(N/A)	3.6	3.1	7.86
Red mulberry	4.2	319	169.4	177	496	(N/A)	3.0	2.1	6.44
Chinaberry	5.5	416	213.0	223	638	(N/A)	2.5	2.7	9.82
Chittamwood	3.4	259	142.7	149	408	(N/A)	2.1	1.7	7.56
Baldcypress	4.7	359	179.4	188	547	(N/A)	1.9	2.3	11.16
Carolina laurelcherry	0.6	46	28.7	30	76	(N/A)	1.5	0.3	1.96
Boxelder	2.9	222	115.2	120	343	(N/A)	1.5	1.5	9.01
Post oak	5.8	439	200.2	209	648	(N/A)	1.5	2.7	17.06
Live oak	4.6	350	155.2	162	513	(N/A)	1.5	2.2	13.49
Eastern cottonwood	7.4	565	223.3	234	799	(N/A)	1.3	3.4	23.49
Bur oak	4.2	315	147.1	154	469	(N/A)	1.3	2.0	13.80
Common crapemyrtle	1.9	145	83.2	87	232	(N/A)	1.2	1.0	7.26
Black willow	3.2	243	117.1	122	365	(N/A)	1.2	1.5	11.78
Other street trees	12.4	938	446.9	467	1,405	(N/A)	5.3	5.9	10.26
Citywide total	206.1	15,643	7,659.7	8,012	23,655	(N/A)	100.0	100.0	9.09

Atmospheric Carbon Dioxide Reductions

Urban forests can reduce atmospheric CO_2 in two ways:

1. Through direct sequestration of CO_2 as woody and foliar biomass.
2. Through the reduction of emissions associated with electric power production and consumption of natural gas by reducing the demand for heating and air conditioning.

Conversely, maintenance activities such as use of vehicles, chain saws, chippers, and other equipment release CO_2 into the atmosphere. Additionally, all trees eventually die and most of the CO_2 that had been stored/sequestered within the woody tissues (biomass) will also be released into the atmosphere through decomposition unless the wood is utilized or recycled. The model used to assign values to the carbon sequestration and storage benefits of trees accounts for these negative carbon releases and provides a net benefit value.

Carbon Dioxide Reductions

Table 8 shows how the reduction of CO_2 is directly related to the species and age composition of the given orest. Reductions of CO_2 due to sequestration and lowered energy plant emissions due to reduced energy use are 448 tons valued at $6,719 ($2.58 per, tree) and 87 tons at a value of $1,248 ($0.50 per tree), respectively, or a total of 535 tons valued at $7,967 ($3.06 per tree). Release of CO_2 from decomposition and tree-care activities is estimated at 17.6 tons valued at -$264 annually. Net CO_2 reduction is 517 tons, valued at $7,761 or $2.98 per tree.

Table 8: CO_2 reductions, releases, and gross benefits produced by trees.

Species	Sequestered (lb)	Sequestered ($)	Decomposition Release (lb)	Maintenance Release (lb)	Total Released ($)	Avoided (lb)	Avoided ($)	Net Total (lb)	Total Standard ($) Error	% of Total Trees	% of Total $	Avg. $/tree
American elm	153,675	1,153	-6,577	-423	-53	31,187	234	177,863	1,334 (N/A)	15.3	17.2	3.35
Sugarberry	145,313	1,090	-2,566	-284	-21	23,099	173	165,563	1,242 (N/A)	14.5	16.0	3.28
Pecan	99,015	743	-5,319	-271	-42	21,043	158	114,467	859 (N/A)	9.1	11.1	3.62
Eastern red cedar	25,054	188	-828	-182	-8	7,596	57	31,640	237 (N/A)	8.9	3.1	1.02
Tree of heaven	47,154	354	-1,104	-151	-9	8,621	65	54,520	409 (N/A)	8.4	5.3	1.87
Shumard oak	86,338	648	-3,717	-235	-30	17,421	131	99,807	749 (N/A)	8.4	9.7	3.42
Cedar elm	44,721	335	-1,304	-132	-11	8,506	64	51,792	388 (N/A)	6.1	5.0	2.44
Green ash	27,572	207	-858	-80	-7	5,310	40	31,943	240 (N/A)	3.6	3.1	2.55
Red mulberry	18,504	139	-543	-57	-4	3,548	27	21,452	161 (N/A)	3.0	2.1	2.09
Chinaberry	30,796	231	-543	-56	-4	4,629	35	34,826	261 (N/A)	2.5	3.4	4.02
Chittamwood	15,897	119	-257	-36	-2	2,884	22	18,489	139 (N/A)	2.1	1.8	2.57
Baldcypress	20,126	151	-844	-54	-7	3,998	30	23,225	174 (N/A)	1.9	2.2	3.55
Carolina laurelcherry	1,987	15	-66	-19	-1	515	4	2,417	18 (N/A)	1.5	0.2	0.46
Boxelder	14,997	112	-320	-30	-3	2,473	19	17,119	128 (N/A)	1.5	1.7	3.38
Post oak	23,039	173	-1,250	-58	-10	4,886	37	26,616	200 (N/A)	1.5	2.6	5.25
Live oak	18,883	142	-984	-47	-8	3,900	29	21,752	163 (N/A)	1.5	2.1	4.29
Eastern cottonwood	25,701	193	-2,194	-67	-17	6,293	47	29,733	223 (N/A)	1.3	2.9	6.56
Bur oak	16,753	126	-867	-44	-7	3,511	26	19,353	145 (N/A)	1.3	1.9	4.27
Common crapemyrtle	3,360	25	-93	-31	-1	1,618	12	4,855	36 (N/A)	1.2	0.5	1.14
Black willow	20,270	152	-465	-33	-4	2,704	20	22,476	169 (N/A)	1.2	2.2	5.44
Other street trees	56,672	425	-2,094	-135	-17	10,443	78	64,885	487 (N/A)	5.3	6.3	3.55
Citywide total	895,827	6,719	-32,793	-2,426	-264	174,186	1,306	1,034,793	7,761 (N/A)	100.0	100.0	2.98

American elm (17%), sugarberry (16%), pecan (11%), and Shumard oak (10%) accounted for over 50% of the CO_2 benefits. Species with the highest per-tree savings were cottonwood (*Populus deltoides* ($6.56), black willow (*Salix nigra*) ($5.44), post oak (*Quercus stellata*) ($5.25), and live oak (*Quercus virginiana*) ($4.29). Total sequestered CO_2 (448 tons) was much greater than reduced CO_2 emissions (87 tons). This can be explained by the fact that Dallas has extremely hot summer months, resulting in high energy use for cooling thus higher levels of CO_2 emissions being released. Again, the shading effect of trees was not a major factor in this study due to the location of the majority of trees within the interior of the greenbelt.

Air Quality Improvement

Urban trees improve air quality in five main ways:

1. Absorbing gaseous pollutants (ozone, nitrogen oxides) through leaf surfaces.
2. Intercepting particulate matter (e.g., dust, ash, dirt, pollen, smoke).
3. Reducing emissions from power generation by reducing energy consumption (Shading Effect).
4. Releasing oxygen through photosynthesis.
5. Transpiring water and shading surfaces, resulting in lower local air temperatures, thereby reducing ozone levels (Transpirational Cooling).

The cooling effect of trees helps to minimize higher air temperatures which would otherwise contribute to increased ozone formation. At the same time, most trees emit various biogenic volatile organic compounds (BVOCs) such as isoprenes and monoterpenes that can contribute to ozone formation. While the ozone-forming potential of different tree species has been shown to vary considerably (Benjamin and Winer 1998), the complex interaction between trees and ozone formation has not been well studied.

Avoided Pollutants

Energy savings result in reduced air-pollutant emissions of nitrogen dioxide (NO_2), small particulate matter (PM_{10}), volatile organic compounds (VOCs), and sulfur dioxide (SO_2) (Table 10). Together, 1,539 lbs of pollutants are avoided annually valued at $5,398 ($2.07 per tree). Avoided emissions of NO_2 and SO_2 due to energy savings are especially important, totaling 1,372 lbs or 89% of all avoided pollution.

Deposition and Interception

Annual pollutant uptake by trees (pollutant deposition and particulate interception) in Turtle Creek is 948 lbs (Table 9) with a total value of $4,370 or $1.68 per tree. Ozone uptake and PM_{10} interception accounts for approximately 76% of the total dollar benefit, an important benefit in a region with an EPA clean air non-attainment status. Benefits from avoided emissions are only slightly greater than from deposition. As Dallas continues to strive for clean air attainment status, thereby reducing its emissions and improving air quality in the region there should be a relatively smaller benefit from deposition as levels of air pollutants decrease.

Table 9: Deposition, avoided and BVOC emissions, and gross air-quality benefits produced by predominant tree species.

	Deposition (lb)				Total	Avoided (lb)				Total	BVOC	BVOC					
Species	O_3	NO_2	PM_{10}	SO_2	Depos. ($)	NO_2	PM_{10}	VOC	SO_2	Avoided ($)	Emissions (lb)	Emissions ($)	Total (lb)	Total ($)	Standard Error	% of Total Trees	Avg. $/tree
American elm	56.6	26.6	65.1	13.1	733	77.0	15.2	14.9	168.9	968	-609.0	-3,812	-171.6	-2,111	(N/A)	15.3	-5.30
Sugarberry	46.2	16.4	42.9	7.4	531	57.5	11.3	11.1	124.9	720	-2.4	-15	315.3	1,237	(N/A)	14.5	3.27
Pecan	39.0	18.3	44.8	9.0	505	51.4	10.2	10.0	113.6	648	-467.1	-2,924	-170.8	-1,771	(N/A)	9.1	-7.47
Eastern red cedar	37.6	12.7	27.4	7.5	412	17.7	3.6	3.6	41.2	228	-12.7	-79	138.5	561	(N/A)	8.9	2.42
Tree of heaven	15.4	7.2	17.7	3.6	199	21.8	4.2	4.2	46.9	272	-115.1	-721	5.8	-250	(N/A)	8.4	-1.14
Shumard oak	31.9	15.0	36.7	7.4	414	43.0	8.5	8.3	94.3	541	-345.2	-2,161	-100.0	-1,207	(N/A)	8.4	-5.51
Cedar elm	15.1	7.1	17.4	3.5	196	21.3	4.2	4.1	46.2	267	-131.7	-824	-12.8	-362	(N/A)	6.1	-2.27
Green ash	9.4	4.4	10.8	2.2	122	13.3	2.6	2.6	28.8	166	-85.2	-533	-11.0	-245	(N/A)	3.6	-2.60
Red mulberry	6.3	3.0	7.3	1.5	82	8.9	1.7	1.7	19.3	111	-53.9	-338	-4.3	-145	(N/A)	3.0	-1.88
Chinaberry	9.2	3.3	8.5	1.5	106	11.5	2.3	2.2	25.1	144	-0.5	-3	62.9	246	(N/A)	2.5	3.79
Chittamwood	5.8	2.1	5.4	0.9	67	7.2	1.4	1.4	15.6	90	-0.3	-2	39.5	155	(N/A)	2.1	2.88
Baldcypress	7.4	3.5	8.5	1.7	96	9.9	1.9	1.9	21.6	124	-79.2	-496	-22.7	-276	(N/A)	1.9	-5.63
Carolina laurelcherry	2.9	1.0	2.1	0.6	32	1.3	0.3	0.2	2.8	16	0.0	0	11.2	48	(N/A)	1.5	1.23
Boxelder	5.0	1.8	4.6	0.8	57	6.1	1.2	1.2	13.4	77	-0.3	-2	33.7	132	(N/A)	1.5	3.48
Post oak	9.1	4.3	10.4	2.1	118	11.9	2.4	2.3	26.4	150	-111.7	-699	-42.8	-431	(N/A)	1.5	-11.35
Live oak	7.4	3.5	8.5	1.7	96	9.4	1.9	1.8	21.0	119	-71.6	-449	-16.4	-233	(N/A)	1.5	-6.14
Eastern cottonwood	12.0	5.6	13.7	2.8	155	15.0	3.0	3.0	33.8	191	-178.5	-1,118	-89.7	-772	(N/A)	1.3	-22.71
Bur oak	6.5	3.1	7.5	1.5	84	8.6	1.7	1.7	19.0	108	-77.6	-486	-28.1	-293	(N/A)	1.3	-8.62
Common crapemyrtle	3.1	1.1	2.9	0.5	36	4.1	0.8	0.8	8.8	51	0.0	0	22.0	87	(N/A)	1.2	2.71
Black willow	5.4	1.9	5.0	0.9	62	6.6	1.3	1.3	14.6	84	-0.4	-2	36.6	143	(N/A)	1.2	4.62
Other street trees	22.4	8.9	22.0	4.3	268	25.6	5.1	5.0	56.4	322	-127.5	-798	22.1	-208	(N/A)	5.3	-1.52
Citywide total	353.6	150.9	369.2	74.2	4,370	429.1	84.6	83.1	942.5	5,398	-2,469.8	-15,461	17.4	-5,693	(N/A)	100.0	-2.19

BVOC Emissions

Biogenic volatile organic compound (BVOC) emissions from trees are relatively large contributing to overall net negative value for air quality (Table 9). The total emissions released as a result of BVOC is 1.2 tons annually with a value of -$15,461. The three tree species with the highest release of BVOC are American elm (609 lbs), pecan (467 lbs), and Shumard oak (345 lbs). However, the species with the lowest per tree value are bur oak, post oak, and Eastern cottonwood with -$8.62, -$11.35, and -$22.71, respectively.

Net Air-Quality Improvement

Net air pollutants removed, released, and avoided totaled 17.4 lbs with an average of .007 lb per tree and are valued at $-5,693 annually or $-2.19 per tree. Trees' ability to improve air quality can vary substantially across species and size classes. Large-canopied trees with large leaf surface areas and low BVOC emissions produce the greatest benefits. Unfortunately, the largest species in the Turtle Creek population, which are also some of the most populous species, tend to be high BVOC emitters. These include American elm (37%), pecan (31%), and Shumard oak (21%) which together account for 89% of total negative net value. Annually, on a per-tree basis, the most valuable tree species include black willow (*Salix nigra*) ($4.62), chinaberry ($3.79), boxelder (*Acer negundo*) ($3.48), and sugarberry ($3.27).

<u>Stormwater-Runoff Reductions</u>

The Federal Clean Water Act regulates municipal stormwater discharge that enters public water sources. Municipal governments are required to outline and submit Best Management Practices for avoiding and reducing pollutant discharge. Fortunately, municipal trees aid in reducing stormwater runoff by intercepting and storing rainfall on their leaves and branches. Reducing the volume of runoff during a storm event helps to minimize both soil erosion potential and the peak flow levels. More specifically, healthy urban trees play an important role in stormwater management in three key ways:

1. Reducing the overall volume of water entering the storm system by leaf and branch absorption.
2. Increased soil health and structure due to the process of root growth and decomposition, thus increasing water infiltration rates that ultimately reduce overland water flow.
3. Reduction of rainfall velocity and the soil impact rate of raindrops through tree canopy interception which reduces soil erosion potential and surface transport rates of water.

Dallas' Turtle Creek trees intercept an estimated 6.7 million gallons (894,239 cubic feet) of rain annually at a value of $66,229 – a substantial reduction in stormwater runoff. Each year the average tree intercepts approximately 2,571 gallons of stormwater, valued at $25.45, annually (Table 10). When evaluating the entire tree population, certain species performed much better at reducing stormwater runoff than others. A tree's ability to intercept rainfall is directly related to its leaf type, as well as total surface area of leaves present (i.e. crown size), branching pattern or the arrangement of branches and their position on the tree, the texture of bark (i.e. smooth bark intercepts less water than rough or deeply furrowed bark), as well as tree size and overall tree shape. These factors all affect the amount of precipitation trees can intercept and hold to avoid direct runoff.

Stormwater reduction benefits ranged from $3 to $99. Trees that performed well on a per tree basis include Eastern cottonwood, post oak, live oak, and bur oak. Poor performers are species with relatively little leaf and stem surface area, such as Carolina laurelcherry (*Prunus caroliniana*) and Eastern red cedar. In terms of percent of total benefit value, American elm accounted for 20%, pecan 14%, and Shumard oak 11% of the total dollar benefit.

Table 10: Annual stormwater reduction benefits produced by predominant tree species.

Species	Total rainfall interception (Gal)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
American elm	1,309,457	12,965	(N/A)	15.3	19.6	32.57
Sugarberry	650,044	6,436	(N/A)	14.5	9.7	17.03
Pecan	963,525	9,540	(N/A)	9.1	14.4	40.25
Eastern red cedar	200,554	1,986	(N/A)	8.9	3.0	8.56
Tree of heaven	285,753	2,829	(N/A)	8.4	4.3	12.92
Shumard oak	742,220	7,348	(N/A)	8.4	11.1	33.55
Cedar elm	307,660	3,046	(N/A)	6.1	4.6	19.16
Green ash	196,107	1,942	(N/A)	3.6	2.9	20.66
Red mulberry	126,675	1,254	(N/A)	3.0	1.9	16.29
Chinaberry	133,826	1,325	(N/A)	2.5	2.0	20.38
Chittamwood	75,074	743	(N/A)	2.1	1.1	13.76
Baldcypress	171,029	1,693	(N/A)	1.9	2.6	34.56
Carolina laurelcherry	10,301	102	(N/A)	1.5	0.2	2.61
Boxelder	73,851	731	(N/A)	1.5	1.1	19.24
Post oak	229,804	2,275	(N/A)	1.5	3.4	59.87
Live oak	182,830	1,810	(N/A)	1.5	2.7	47.64
Eastern cottonwood	341,179	3,378	(N/A)	1.3	5.1	99.35
Bur oak	161,069	1,595	(N/A)	1.3	2.4	46.90
Common crapemyrtle	31,094	308	(N/A)	1.2	0.5	9.62
Black willow	91,610	907	(N/A)	1.2	1.4	29.26
Other street trees	405,707	4,017	(N/A)	5.3	6.1	29.32
Citywide total	6,689,369	66,229	(N/A)	100.0	100.0	25.45

Property Values and Other Benefits

While the benefits that community trees provide described above may be more easily understood, there are other less tangible social benefits associated to urban trees that are more difficult to assess and place monetary values on. Social benefits such as beauty, privacy, shade that increases human comfort, wildlife habitat, and sense of place and well-being are are harder to capture in monetary terms. However, the methodology employed here attempts to determine tree value through property values where the trees exist. For example, McPherson et al. 2006 estimated the value of these "other" benefits by comparing the differences in sales prices of houses associated with trees. The study indicates that the difference in sales price may be interpreted as the willingness of buyers to pay for the benefits and costs associated with trees. In other words, the sales price of the home reflects public perception of what urban tree benefits and costs should be.

One limitations to using this approach is that while the local Dallas average home sale prices of ~$158,000 in December 2009 (Aol Real Estate 2010) or ~$142,000 on average for the Q4 of 2009 (CNN 2010) can be accounted for in the STRATUM program the culture of perception of trees and their value may be different than that of Charlotte, NC (the Reference City) and therefore not accurately reflected in the estimation of aesthetic benefits here. However, these first-order estimates may still be used as a basis for understanding consumer perception on the benefits of community trees.

The estimated total annual benefit associated with aesthetics and other less tangible benefits is $115,194 or $44.27 per tree on average (Table 11). The level of this benefit is related to the local median sales price in December 2009 for single family homes ($158,766 in Dallas (Aol Real Estate)), as well as tree growth rates as determined from the reference city. This $44 per tree benefit is in line with values from other communities that have similar median home values. For example, benefits in Glendale, AZ, Minneapolis, MN, and Fort Collins, CO, average $22, $44, and $52 per tree (McPherson et al. 2002, 2005, 2005) where the median home sales prices are $144,000, $218,000, and $212,000, respectively. Tree species that produce the highest average annual aesthetic benefits are Eastern cottonwood ($89 per tree), post oak ($79 per tree), live oak ($69 per tree), and bur oak ($68 per tree), while laurelcherry ($2 per tree), Eastern red cedar ($7 per tree), and crapemyrtle (*Lagerstroemia indica*) ($14 per tree) provide the least benefits.

Table 12: Annual Aesthetic/Other Benefits of Turtle Creek Trees by Species

Species	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
American elm	22,821	(N/A)	15.3	19.8	57.34
Sugarberry	13,118	(N/A)	14.5	11.4	34.70
Pecan	14,006	(N/A)	9.1	12.2	59.10
Eastern red cedar	1,650	(N/A)	8.9	1.4	7.11
Tree of heaven	8,480	(N/A)	8.4	7.4	38.72
Shumard oak	12,670	(N/A)	8.4	11.0	57.86
Cedar elm	7,391	(N/A)	6.1	6.4	46.49
Green ash	4,488	(N/A)	3.6	3.9	47.75
Red mulberry	3,130	(N/A)	3.0	2.7	40.65
Chinaberry	2,573	(N/A)	2.5	2.2	39.59
Chittamwood	1,654	(N/A)	2.1	1.4	30.63
Baldcypress	2,952	(N/A)	1.9	2.6	60.24
Carolina laurelcherry	77	(N/A)	1.5	0.1	1.97
Boxelder	1,405	(N/A)	1.5	1.2	36.96
Post oak	3,014	(N/A)	1.5	2.6	79.33
Live oak	2,617	(N/A)	1.5	2.3	68.86
Eastern cottonwood	3,012	(N/A)	1.3	2.6	88.59
Bur oak	2,302	(N/A)	1.3	2.0	67.71
Common crapemyrtle	440	(N/A)	1.2	0.4	13.75
Black willow	1,511	(N/A)	1.2	1.3	48.73
Other street trees	5,882	(N/A)	5.3	5.1	42.94
Citywide total	115,194	(N/A)	100.0	100.0	44.27

Chapter Four—Management Implications

Since its inception in the late 19th century this area has received much interest from both residents and visitors alike. Today this area still represents the original intent, which was to create an urban park environment that not only served the community but was also part of the community. Through its development the park has become one that includes some of the oldest trees in the city as well as many younger and newly planted trees. Proper management dictates that new trees continue to be added to the forest in order to replace ones that reach maturity and near the end of their productive lives. While this study may simply provide a one-time analysis of the current state of the tree resource, it also enables the city to forecast what the potential future trends within the forest might look like. Given the current status of Turtle Creek's tree population, what are the likely stand dynamics? In other words, how does the current condition, both structurally and health wise, affect the future quality of the forest and in turn the future benefits? What are the management priorities that may help the city create a sustainable urban forest that will ensure net benefits over the long term? Such management should include steps that enable adequate structural complexity (species and age diversity), healthy trees that are native or well-adapted to their site, a well stocked population, and fiscal efficiency. Goals must be clearly defined by the city so that both progress and effectiveness may be measured over time.

Resource Complexity

Developing a more diverse species and age population should be a priority for the City of Dallas Parks and Recreation Department. Unfortunately, the preexisting inventory used for this analysis did not include data for trees less than 4" in diameter. Therefore, an important cohort within the overall population of trees has not been assessed or reported and therefore implications for management cannot be made for this age class. It should be a priority to determine the species composition within this young age class to help evaluate the future stand dynamics as the entire population matures.

American elm trees account for 15% of the total population and produce 22% of total benefits, but are susceptible to Dutch elm disease, which is spread by the elm bark beetle (*Scolytus multistriatus*). While this disease has not reached epidemic proportions in the DFW region, unlike areas of the Northeast and Midwest, it has been detected in the City of Flower Mound located north west of Dallas in Tarrant and Denton Counties just last year in 2009. If this disease were to develop into a larger scale problem the principal portion of Turtle Creek's forest would be at risk. Monitoring of this species should be a priority. Oak wilt disease, caused by the fungus *Ceratocystis fagacearum* (Bretz) Hunt, is also an important risk factor that should be managed for. Shumard oak, another one of the top ten most prevalent species is highly susceptible to this disease and could have serious losses if the disease is not monitored. Both sugarberry and cedar elm are preferred hosts for mistletoe which is very unsightly and if left uncontrolled could have adverse effects on tree growth.

Secondly, a majority of the trees fall within the maturing age class. In fact, over 68% of all trees fall within the 6-18" diameter range. This means that as these maturing trees age, the benefits they produce will also increase. Unfortunately, some of the species which dominate the maturing age class, such as tree of heaven, an invasive exotic and Eastern red cedar are less desirable in terms of benefits produced. Thus, over the next 50 years, the health, longevity, and species type will influence the stability and productivity of the population's future canopy. Management must be directed at these age classes to ensure long term stand health and in turn maximization of public benefits as these species begin to take over the canopy position currently dominated by American elm.

Finally, critical to the future of Dallas' forest is the selection of transplants that will grow to replace the canopy cover provided by American elms. Ideally, a more diverse mix of species will be planted: some proven performers, some species that are more narrowly adapted, and a small percentage of new introductions for evaluation. Proven performers based on a per tree basis include eastern cottonwoods, post oaks, and live oaks. However, the best performing species as seen by percentage of total benefits provided annually are American elm, pecan, and Shumard red oak. Many individuals of these species make up the mature age classes and thus have demonstrated their ability to thrive in the local conditions long term.

Other species that have proven well-suited in certain situations are bur oak (*Quercus macrocarpa*), green ash, bald cypress (*taxodium distichum*), lacebark elm (*Ulmus parvifolia,*) and Italian stone pine (*Pinus pinea*). Some underutilized less common Texas native species that might be favorable for new introductions might include rusty blackhaw (*Viburnum rifidulum*), bigtooth maple (*Acer grandidentatum*), goldenraintree (*Koelreuteria paniculata*), and chinkapin oak (*Quercus muehlenbergii*). These species have been used infrequently in and around the Dallas region and provide an opportunity to diversify the urban tree canopy of Turtle Creek while promoting native species.

Under the right conditions and management the above species should help produce the important benefits in the future that the community depends upon. Among the species shown, only rusty blackhaw is a small species, thus the majority of new introductions would supply a nice mix of medium and large species ultimately enhancing the structural complexity and delivery of benefits in the long term.

Resource Extent

Canopy cover, or the total squared leaf surface area of the forest, is the most direct indicator of the urban forest's potential output of benefits. As canopy cover increases, so do the benefits produced by leaf area. Maximizing the receipt of these potential benefits is dependent on the investments made in managing the canopy cover of the dominant trees within the population and promoting the health and growth of the individuals that will replace them as they age and die. With 46% of the surface area of Turtle Creek covered by tree canopy, increasing the tree canopy cover is not a main priority rather, developing strategic management to ensure its sustainability into the future and that its composition will be that of the most beneficial species should be a main objective. This may be accomplished by identifying overall plantable space and selecting sites near the oldest trees within the population to plan for replacement. Selection of large species when appropriate is encouraged.

Maintenance

Retaining and enhancing Dallas' canopy cover is a main concern as is true with nearly any community. Possible risk of loss of American elms due to disease mixed with the fact that it is the most populous species creates the opportunity for a large scale reduction in the tree canopy if disease were to become widespread. Additionally, risk of oak wilt disease will play a large role in species selection. While city funds have been in recent decline, investment in the community forest now can mean large savings later and also promote increased health of the tree population overall.

This analysis provides some basic accounting of maintenance needs, however specific maintenance recommendations listed in the inventory conducted by HALFF and Associates, Inc. should be followed up on and individual trees visited. For example, data from the inventory shows that the majority of trees are generally in good health, with approximately 2% of the population found dead and only 1% with significant insect, fungus, and/or bacterial-related stress concerns. Furthermore, 7.2% (188) require some level of pruning, 0.5% (12) requires cabling/bracing, and 1.2% (31) of all trees may require removal. It would be a good idea to revisit the inventory to determine species specific concerns and/or individual maintenance needs. Knowing which species tend to be more problematic will help in planning to reduce high maintenance species from the population as well as to address potential risks from dead and/or diseased individuals.

In general, the city should strongly consider the development of a regular pruning cycle (e.g. 5-year interval). Properly timed pruning can reduce future structural problems in trees and save money on future maintenance. The citywide age distribution of all trees does not correspond to the "ideal" distribution as described above, having elevated numbers of maturing trees, adequate numbers of young trees and lower numbers of mature trees (see Figure 4). This distribution suggests that a strong young-tree-care program is imperative, as is targeted maintenance for maturing trees. Pruning young trees biannually for structure and form will more than pay off in the long term because fewer resources will be required to maintain them in the future. Regular inspection and pruning of maturing trees will insure that they transition into mature trees that will provide optimal benefits for many years.

Chapter Five—Conclusions

The approach used in this analysis utilized a preexisting inventory in order to describe the structural characteristics of the tree population. The forest structure was then used in order to assess the environmental and social benefits of the trees. These benefits data are based on established tree-sampling, numerical-modeling, and statistical methods (McPherson et al. 2006) utilized to establish what is termed a “Reference City” (see Appendix A). They allow for a reliable assessment of the ecosystem services provided by the measured population. In addition, general management needs have also been identified and discussed.

Turtle Creek’s trees are a valuable public asset with an estimated replacement value of $9.2 million, providing approximately $207,000 ($80 per tree) in gross annual benefits. Aesthetic and property value increase benefits to the community account for the majority of all benefits received with 56%. However, stormwater- reduction benefits are also significant contributing 32% of all benefits. Thus, it is apparent that trees can play a real role in providing and maintaining the environmental and aesthetic qualities of the community along the greenbelt as well as the city at large.

Dallas should assess its total expenditures for the various management activities undertaken throughout the year in order to determine cost effectiveness for its program. Knowing the actual expenses by maintenance activity will allow the city to understand which activities are more costly and what management strategies might be employed to lower those costs. Ultimately, a net annual value of benefits may be obtained once costs are directly considered. As the resource matures, continued investment in management is critical to insuring that residents receive a greater return on investment in the future.

Municipal trees are a very dynamic resource and the trees within the Turtle Creek greenbelt are an important component to the City of Dallas’ urban forest. The trees provide important benefits and help to improve the quality of life in the city. However, a commitment to consistent management must be employed in order to maximize and sustain the production of benefits into the future. The focus should be to perpetuate the tree canopy into the future and at the same time allow for development and general growth.

There are five main management recommendations derived from this analysis: 1) Continue and enhance investment in the formal management of the tree resource including staff specifically charged with the care of all public trees including street and park trees; 2) Utilize the HALFF data to locate dead, dying, and diseased (risk trees) that may require removal; 3) Provide maturing trees, poised to create the future canopy, with a 5-year inspection/pruning cycle to insure their health and longevity, since the majority of benefits in the community forest will be derived from this age class; 3) Focus on young-tree care to reduce future long-term tree-care; and 4) Continue to provide adequate diversity through systematic, planned tree planting including planting large-stature tree species where space permits. These recommendations should be part of the city’s overall goal of creating an urban forest resource that is both functional and sustainable.

Appendix A: Population Summary of Turtle Creek Park trees in order of predominance by DBH class and tree type

	DBH Class (in)									
Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total Standard Error
Broadleaf Deciduous Large (BDL)										
American elm	0	31	148	121	55	30	7	4	2	398
Pecan	0	23	93	46	29	25	11	8	2	237
Tree of heaven	0	45	134	36	2	2	0	0	0	219
Shumard oak	0	22	80	49	42	19	6	1	0	219
Cedar elm	0	24	75	45	13	2	0	0	0	159
Green ash	0	14	41	30	7	1	1	0	0	94
Red mulberry	0	23	31	19	1	3	0	0	0	77
Baldcypress	0	1	23	6	14	4	1	0	0	49
Post oak	0	0	5	10	8	12	3	0	0	38
Eastern cottonwood	0	2	1	4	5	9	6	3	4	34
Bur oak	0	1	10	9	6	4	4	0	0	34
bdl OTHER	0	2	9	9	10	7	0	3	1	41
Total	**0**	**188**	**650**	**384**	**192**	**118**	**39**	**19**	**9**	**1,599 (±NaN)**
Broadleaf Deciduous Medium (BDM)										
Sugarberry	0	72	207	73	24	2	0	0	0	378
Chinaberry	0	5	33	22	5	0	0	0	0	65
Chittamwood	0	11	36	6	1	0	0	0	0	54
Boxelder	0	7	20	6	4	0	0	1	0	38
Black willow	0	3	10	9	6	2	0	0	1	31
bdm OTHER	0	6	31	13	6	3	0	0	1	60
Total	**0**	**104**	**337**	**129**	**46**	**7**	**0**	**1**	**2**	**626 (±NaN)**
Broadleaf Deciduous Small (BDS)										
Common crapemyrtle	0	1	11	19	0	0	0	0	1	32
bds OTHER	0	13	11	1	0	0	0	0	0	25
Total	**0**	**14**	**22**	**20**	**0**	**0**	**0**	**0**	**1**	**57 (±NaN)**
Broadleaf Evergreen Large (BEL)										
Live oak	0	4	14	3	9	4	2	2	0	38
bel OTHER	0	0	0	0	0	0	0	0	0	0
Total	**0**	**4**	**14**	**3**	**9**	**4**	**2**	**2**	**0**	**38 (±NaN)**
Broadleaf Evergreen Medium (BEM)										
bem OTHER	0	0	2	3	0	0	0	0	0	5
Total	**0**	**0**	**2**	**3**	**0**	**0**	**0**	**0**	**0**	**5 (±NaN)**
Broadleaf Evergreen Small (BES)										
Carolina laurelcherry	0	22	17	0	0	0	0	0	0	39
bes OTHER	0	1	0	0	0	0	0	0	0	1
Total	**0**	**23**	**17**	**0**	**0**	**0**	**0**	**0**	**0**	**40 (±NaN)**
Conifer Evergreen Large (CEL)										
cel OTHER	0	0	1	3	1	0	0	0	0	5
Total	**0**	**0**	**1**	**3**	**1**	**0**	**0**	**0**	**0**	**5 (±NaN)**
Conifer Evergreen Medium (CEM)										
Eastern red cedar	0	33	126	63	6	4	0	0	0	232
cem OTHER	0	0	0	0	0	0	0	0	0	0
Total	**0**	**33**	**126**	**63**	**6**	**4**	**0**	**0**	**0**	**232 (±NaN)**
Conifer Evergreen Small (CES)										
ces OTHER	0	0	0	0	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0 (±NaN)**
Grand Total	**0**	**366**	**1,169**	**605**	**254**	**133**	**41**	**22**	**12**	**2,602 (±0)**

Appendix B – iTree Streets (STRATUM) Acknowledgements and Methodology[1]

i-Tree Streets is an adaptation of the Street Tree Resource Assessment Tool for Urban forest Managers (STRATUM), which was developed by a team of researchers at the USDA Forest Service, PSW Research Station. The STRATUM application was conceived and developed by Greg McPherson, Scott Maco, and Jim Simpson. James Ho conducted original STRATUM programming. The numerical models utilized by STRATUM to calculate tree benefit data are based on years of research by Drs. McPherson, Simpson, and Qingfu Xiao (UC Davis). Reference city data on tree growth and geographic variables were developed under the direction of Paula Peper, Kelaine Vargas and Shelley Gardner. The reference city and subsequent growth models utilized in this analysis were derived from research conducted within the city of Charlotte, North Carolina (McPherson et al. 2006). A full description of the model development and background research may be obtained at the following link http://www.fs.fed.us/psw/programs/cufr/treeguides.php . The report format for this analysis was modeled after McPherson et al. 2005, City of Minneapolis, Minnesota Municipal Tree Resource Analysis technical report.

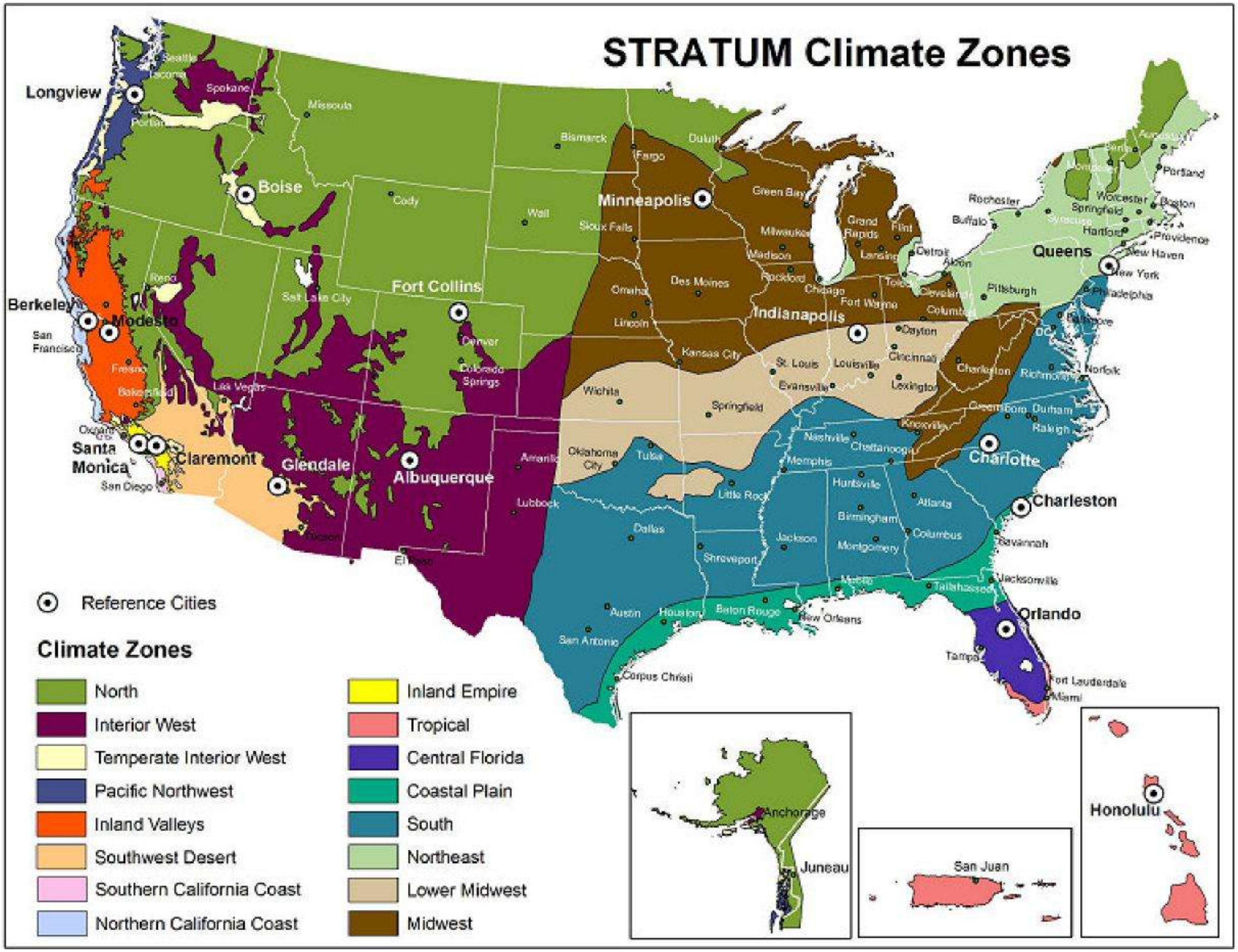
Project analysis output by STRATUM is specific to a regional climate zone (Appendix C). The STRATUM program uses data specific to each zone to model the costs and benefits of trees. In order to calculate tree-related benefits for a city, STRATUM must know what species are most likely to be found in the region, how big the trees are expected to grow, how quickly they will reach mature size and what leaf area they will have. These factors vary by location due to differences in growing conditions, management practices, climate, and soils. Nineteen regional tree-growth zones, based on aggregation of climate zones from Sunset's National Garden Book (Eyre 1997), have been identified for the nation (Figure 5). Cities within a zone are assumed to have similar species of trees with similar growth and size traits.

The regional tree data are based on measurements from a Reference City designated within each region, which is intended to represent the average regional climate, soil, and species conditions. Approximately 800 trees are randomly sampled—40 trees of each of the 20 most common species. For each species, five to ten trees from each diameter at breast height (dbh) size class are measured for dbh, tree height, crown diameter, crown shape, and tree condition. Planting dates are determined from city records and other local sources. Crown volume and leaf area are estimated from computer processing of tree-crown images taken with a digital camera. This method has shown greater accuracy for open-grown trees than other techniques (±20% of actual leaf area) (Peper and McPherson 2003) while avoiding the need to destructively sample. Regression analyses are used to determine regionally specific growth curves, so that the tree-related benefits can be estimated for each year of a tree's life.

STRATUM's economic analyses use regional energy prices, property values, water prices and stormwater costs. Regional energy prices, typical energy use, and water prices are collected from the utility companies in the Reference City. Property values and land-use distribution (single family residence, multi-family residence, commercial, etc.) are determined from local data. Air pollutant emissions are calculated based on the regional mix of fuels used to produce electricity, natural gas consumption, and hourly weather data. Stormwater costs are estimated with the help of local stormwater officials. Prices for trees and tree maintenance are determined from surveys of municipal foresters and local arborists. All this information is incorporated into STRATUM as regional default values. However, default values such as benefit prices can be adjusted to better reflect local conditions. Each Reference City is the basis for the regionally specific modeling capabilities of STRATUM and also serves as the basis for CUFR's Community Tree Guides located at the website provided earlier in this appendix. For more information on i-Tree Streets specifically, or i-Tree in general, please visit www.itreetools.org .

1 Summary of STRATUM methodology taken from and available at itreetools.org

Appendix C: STRATUM Climate Zones with Reference Cities



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