City of Cheyenne, Wyoming

Municipal Tree Resource Analysis

BY

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EXECUTIVE SUMMARY

Street trees in Cheyenne are comprised of two distinct populations, those managed by the city's Urban Forestry Division (UFD) and those inspected by the UFD but managed by private property owners. Over the years Cheyenne has invested millions in its municipal forest. The primary question that this study asks is *whether the accrued benefits from Cheyenne's street trees justify the annual expenditures?*

This analysis combines results of a 1992 citywide inventory with benefit-cost modeling data to produce four types of information (Maco 2003):

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

RESOURCE STRUCTURE

- Based on the 1992 UFD inventory there were of 17,010 municipal trees in Cheyenne. Publicly managed trees accounted for 48% (8,103) of the total, while privately cared for trees comprised the remaining 52% (8,907).

- There are many opportunities to increase the resource extent. Approximately 6,300 sites—41% of all street tree-planting sites—were unplanted. Conversely, the parks are fully stocked

- Citywide, the resource represented 58 different tree species, a notable number considering climate restrictions. However, because many were newer introductions to the city and few in number, overall diversity was low.

- Having the most leaf area and canopy cover, Cottonwood and Siberian elm were the dominant street tree species in Cheyenne, contributing over 50% of the total tree leaf area and 60% of the total canopy cover. Ponderosa/Austrian pine, Blue spruce, and Cottonwood dominated park tree plantings.

- The age structure for all public trees in Cheyenne differed from the ideal only in having slightly fewer numbers of mature or older trees and almost 12% more newly out-planted trees. This increase in new plantings may assist in maintaining a flow of benefits that could otherwise drop due to a gap in street tree planting that appears to have occurred between 12 and 20 years ago.

RESOURCE FUNCTION AND VALUE

- Because of Cheyenne's severe climate conditions, energy savings from trees are higher than those that would be found in more sheltered locations. Electricity and natural gas saved annually from both shading and climate effects totaled 1,175 MWh and 21,370 Mbtu, respectively, for a total retail savings of $186,986 ($10.99/tree). Benefits from conifers in parks ($6.27/tree) exceeded street conifer benefits ($3.68/tree), but large deciduous street trees produced six times the benefits of large deciduous park trees.

- Citywide, municipal trees sequestered 664 tons of the greenhouse gas carbon dioxide. The same trees offset an additional 1,120 tons through reductions in energy plant emissions. Street trees had an annual net sequestration rate of approximately 491 tons and reduced emissions by another 788 tons. The combination of these savings was valued at $29,135 ($1.71/tree) annually.

- Annual air pollutant uptake by tree foliage (pollutant deposition and particulate interception) was 2.3 tons combined. The total value of this benefit for all street trees was $8,429, or about $0.50/tree.

- The high biogenic volatile organic compound (BVOC) emission rates associated with the city's predominant species was counteracted by energy savings associated with less fossil fuel consumption (due to the shade and climate effects of the trees). The resultant net benefit was approximately $3,480 or $0.20/tree.

- The ability of Cheyenne's municipal trees to intercept rain—thereby avoiding storm-water runoff—was estimated at 760,191 ft^3 annually. The total value of this benefit to the city was $55,301. Citywide, the average street tree intercepted 334 gallons, valued at $3.25, annually.

- The estimated total annual benefit associated with property value increases and other less tangible benefits was approximately $403,000 or $24/tree on average. American elm ($44/tree), and Hackberry ($39/tree) were on the high end, while Pinyon pine ($3/tree), Juniper species ($4/tree), Birch ($8/tree), and Quaking aspen ($11/tree) averaged the least benefits.

- Overall, annual benefits were determined largely by tree size, where large-stature trees typically produced greater benefits. For example, average small or young trees produced $19/tree in benefits, maturing medium-sized trees produced $38/tree, mature large trees produced $66/tree, and large old trees produced annual benefits of $80/tree.

- The municipal tree resource of Cheyenne is a valuable asset, providing approximately $686 thousand ($40/tree) in total annual benefits to the community. The city currently spends approximately $19/tree on their care. Over the years Cheyenne has invested millions in its municipal forest. Citizens are now receiving a relatively large return on that investment – receiving $2.09 in benefits for every $1 spent on tree care. Continued investment in management is critical to insuring that residents receive a greater return on investment in the future.

RESOURCE MANAGEMENT NEEDS

- Achieving resource sustainability requires increasing diversity by balancing new plantings of proven, long-lived species with newer successful introductions, maximizing available growth space to provide the largest amount of leaf area and canopy coverage as the trees mature. Continued replacement of senescent Cottonwood and Siberian elm with a variety of long-lived medium and large-stature broadleaf deciduous tree species is recommended.

- Focusing planting efforts along streets where stocking levels are lowest will improve the distribution of benefits provided to all neighborhoods. To this end a current inventory of all Cheyenne street trees will aid in overseeing and tracking management.

- Tree health and pruning management needs for street trees were substantial compared to well-maintained park trees. Extensive public education on appropriate pruning and irrigation frequencies to demonstrate the resultant beneficial effects on tree health is necessary; this could assist in improving the functionality, longevity, and the overall benefits produced by street trees. Functionality and longevity would be further bolstered through the establishment of a consistent pruning program for street trees.

Cheyenne's street trees are a fantastically dynamic resource. Managers of this resource and the community alike can delight in knowing that street trees do improve the quality of life in Cheyenne, but they are also faced with a fragile resource that needs constant care to maximize and sustain these benefits through the foreseeable future. In a city where the climate poses a constant challenge to tree growth and health, this is no easy task. The challenge will be to maximize net benefits from available growth space over the long-term, providing a resource that is both functional and sustainable.

CHAPTER ONE—INTRODUCTION

Cheyenne's Urban Forestry Division (UFD) manages approximately 8,900 trees along streets and 8,100 trees in parks. The municipal forest is comprised of two distinct populations, those managed and maintained entirely by the Division (park trees) and those overseen by the Division but predominantly maintained by private property owners (street trees). The UFD believes that the public's investment in stewardship of Cheyenne's urban forest produces benefits that outweigh the costs to the community. Cheyenne, the state capital and largest city in Wyoming, is an active economic, cultural and political center for the northern plains. With population growth increasing nearly 6 percent over the past 10 years to 53,011 citizens, current community goals include maintaining and enhancing the integrity of community neighborhoods, retaining neighborhood character and providing high quality residential neighborhoods. Research indicates that healthy city trees can mitigate impacts of development on air quality, climate, energy for heating and cooling buildings, and storm-water runoff. Healthy street trees increase real estate values, provide neighborhoods with a sense of place, and foster psychological health. Street and park trees are associated with other intangibles such as increased community attractiveness and recreational opportunities that make Cheyenne a more enjoyable place to work and play. Cheyenne's urban forest creates a setting that helps attract tourism and retain businesses and residents.

However, in an era of dwindling public funds and rising expenditures, residents and elected officials often scrutinize expenditures that are considered "non-essential" such as planting and management of the municipal forest. Although the current program has demonstrated its economic efficiency, questions remain regarding the need for the level of service presently provided. Hence, the primary question that this study asks is *whether the accrued benefits from Cheyenne's street trees justify the annual expenditures?*

In answering this question, information is provided to:

1. Assist decision-makers to assess and justify the degree of funding and type of management program appropriate for this city's urban forest.
2. Provide critical baseline information for the evaluation of program cost-efficiency and alternative management structures.
3. Highlight the relevance and relationship of Cheyenne's municipal tree resource to local quality of life issues such as environmental health, economic development, and psychological health.
4. Provide quantifiable data to assist in developing alternative funding sources through utility purveyors, air quality districts, federal or state agencies, legislative initiatives, or local assessment fees.

This report consists of seven chapters and four appendices:

Chapter One—Introduction: Describes purpose of the study.

Chapter Two—Cheyenne's Municipal Tree Resource: Describes the current structure of the street tree resource.

Chapter Three—Costs of Managing Cheyenne's Municipal Trees: Details management expenditures for publicly and privately managed trees.

Chapter Four—Benefits of Cheyenne Municipal Trees: Quantifies estimated value of tangible benefits and calculates net benefits and a benefit-cost ratio for each population segment.

Chapter Five—Management Implications: Evaluates relevancy of this analysis to current programs and posits management challenges with goals of street tree management.

Chapter Six—Conclusion: Final word on the use of this analysis.

Chapter Seven—References: Lists publications cited in the study and the contributions made by various participants not cited as authors.

Appendix A: Tree Distribution.

Appendix B: Describes benefits, procedures and methodology in calculating structure, function, and value of the street tree resource.

Appendix C: Species Code and Relative Performance Index Reference List.

Appendix D: Total Street Right-of-Way and Park Tree Numbers.

CHAPTER TWO—CHEYENNE'S MUNICIPAL TREE RESOURCE

HISTORY AND CURRENT MANAGEMENT

Initially established as a construction camp for the Union Pacific Railroad, the City of Cheyenne was founded in 1867. By 1875 over 5,000 people lived within the city. Settlement came so quickly the town was nicknamed "Magic City of the Plains"; however, tree planting was a slow and challenging process. Nine years after establishment, Mrs. Nannie Steel reported there were only 12 trees in Cheyenne (Cheyenne Botanic Gardens 2004). In 1878, James Flood Jenkins planted his first of many trees in the city. Mr. Jenkins was instrumental in establishing the first Cheyenne Arbor Day in 1882 and many subsequent plans for tree planting, maintenance and park treeing and development (Jenkins undated personal memoirs).

Climate extremes, high elevation (6,062ft), and coarse alkaline soil with little water-holding capacity presented these early citizens with one of the harshest growing climates in the United States. That has not changed in the 137 years since establishment. Thirty-year average minimum and maximum temperatures range from 14.8EF to 81.9EF, respectively, with extremes of -34EF to 100EF. Cheyenne has the highest incidence of hailstorms in the nation (averaging 10 per year), receives an average 15 inches of precipitation annually, and is the fourth windiest city in the nation (13 mph average). Despite these conditions the city has a highly regarded tree program and has received recognition as a Tree City USA for 22 years, as well as 7 Growth Awards and 2 Merit Awards from the National Arbor Day Foundation. Additionally, the program received international recognition, earning a Gold Leaf Award from the International Society of Arboriculture.

In 2003 the UFD employed 8 full time staff to manage and maintain municipal trees. The city is responsible for the management and maintenance of trees and all other woody vegetation on all public properties including parks, golf courses, cemeteries, medians, triangles, islands, and other city maintained public lands. Although tree maintenance on street right-of-way (ROW) is the responsibility of each homeowner or business, residents are required to consult with the City Forester before any tree trimming, planting, or removal is conducted. Additionally, the Division provides education programs and other information for citizens, conducts tree inspections on residential lots, tests, licenses and regulates commercial arborists and pesticide applicators within the city, and provides planning and planting advice for new tree installations. The UFD also provides citizens with a wealth of information on Cheyenne trees, tree care, ordinances, and current issues affecting the urban forest on a well-managed website (http://www.cheyennetrees.com). Residents receive an initial 30-day notice when their trees require maintenance. If the required work is not completed after second notification, the UFD will put the work out to bid and bill the property owner. However, the city ultimately assumes responsibility for the cost if the money cannot be collected.

In this report, all city-maintained trees are referred to as “park” trees. “Street” trees are resident maintained trees in public rights-of-way, the majority of which are planting strips adjacent to residences or businesses.

In 1992, the Division conducted the first full tree inventory for the city. In 2001, a partial inventory for the core area of town was completed and currently a park tree evaluation is being conducted on all city-maintained trees. This year, the Davey Resource Group will re-inventory the privately cared for trees. Approximately 1,730 park trees were pruned in 2001, a year selected for this study because it represents normal maintenance trends. After an initial training prune within 2.5 years of planting, trees are generally in one of 3 different trim cycles. Generally, large park trees (>40 ft) are pruned every 7 years. Medium park (20-40 ft) trees are pruned every 6 years and small trees (<20 ft) are trimmed every 5 years for structure and form. However, this pruning cycle is not the same for all species. A training pruning event may occur on the same tree more than once per year. Larger, senescent trees such as Cottonwoods and Siberian elms may be pruned every one to two years to promote longevity. Currently, maintenance is not following this norm because trees are entering their 5th year of drought and the second year of mandatory watering restrictions. As a result, many trees have significant yearly dieback and require a shortened pruning cycle. Additional monitoring to detect pest problems is performed regularly, and treatments are applied as needed. Increased pest problems are a secondary, and potentially devastating, effect of the on-going drought. Storm damage cleanup, root pruning, and other emergency activities are also performed on an as-needed basis.

On average, about 140 trees are removed from city streets and parks each year. However, the effect of extended drought has increased that number to 179 removals in 2003. In 2003, about 670 trees were planted, more than double the number planted in 2001. Trees are planted annually, following guidelines documented in several brochures that can be obtained from the city website. Removed trees are replaced, either with 2” ball and burlap (B&B) trees or bareroot stock. Trees are selected to fit the available space and match the challenging growing conditions. The UFD continuously reviews tree species performance and maintenance procedures in an effort to maximize tree growth and longevity. Given the growing conditions, the UFD’s focus for the past 12 years has been to plant as diverse of a mix of species as possible to increase protection against catastrophic loss.

TREE NUMBERS

Based on the 1992 full inventory of municipal trees, there were 17,010 street and park trees in Cheyenne (Table 1). The park trees, managed entirely by the UFD, accounted for less than half (47.6%) of the total municipal tree population, while privately cared for trees comprised the larger portion (52.4%).

Table 1. Street right-of-way and park tree numbers by area.

Area	Street ROW	Parks	All	% of total population
Residential	7,605	431	8,036	47.2
Downtown	1,300	15	1,315	7.7
Parks	2	4,909	4,911	28.9
Golf Courses	-	1,665	1,665	9.8
Cemetery	-	1,083	1,083	6.4
Citywide Total	8,907	8,103	17,010	100.0

Large-stature coniferous and broadleaf trees composed 84% of Cheyenne's entire municipal tree population. Large-sized broadleaf deciduous trees were the most prevalent tree type citywide (Table 2) accounting for over 57% of the trees. Conifers accounted for almost a third of all trees planted, with nearly half of those in parks (49.6%) and 14% on streets. Medium-stature trees were the least abundant (2.4%) when compared with all species, with no medium-size conifers represented in the population. Generally, parks tend to be dominated by conifers, particularly Ponderosa/Austrian pine and Blue spruce, whereas Cottonwood and Siberian elm are the most prevalent street trees.

Table 2. Citywide street tree numbers by mature size class and tree type.

Tree type	Street				Park				Total			
	Small	Medium	Large	% of total	Small	Medium	Large	% of total	Small	Medium	Large	% of total
Broadleaf deciduous	782	333	6528	85.8	761	69	3254	50.4	1543	402	9782	68.94
Coniferous	340	-	924	14.2	412	-	3607	49.6	752	-	4531	31.06
% of total	12.6	3.7	83.7	100	14.5	0.9	84.7	100	13.5	2.4	84.1	100

SPECIES COMPOSITION AND RICHNESS

There were a total of 58 different tree species in the tree inventory database. This is roughly equivalent to the mean of 53 species reported by McPherson and Rowntree (1989) in their nationwide survey of street tree populations in 22 US cities. Considering climatic restrictions on plant growth in Cheyenne, the existing species richness indicates planning forethought, experimentation with new species, and successful expansion upon the limited planting palette available to the area. The predominant park tree species (Table 3) were Colorado blue spruce (*Picea pungens*, 22.5%), Ponderosa/Austrian pine (*Pinus ponderosa/nigra*, 18.2%) and Cottonwood (*Populus sp*., 17.6%). Note that Ponderosa and Austrian pine were combined in the inventory and their individual contributions to the total population are unknown. Cottonwood was also the most common street tree species, with 2,038 trees accounting for 23% of the population. There were 1,472 Siberian elms (*Ulmus pumila*), making them the second most common street tree (16.5%).

Table 3. Top five species in the park and street populations listed in order by percent (in parentheses) of total tree management areas.

	Area	1st	2nd	3rd	4th	5th	Tot Trees
Park (includes median, island, triangles)	1	Blue spruce (25.4)	Ponderosa/Austrian pine (20.7)	Cottonwood/poplar (9.4)	Green ash (5.2)	Crabapple (4.4)	405
	2	Crabapple (66.7)	Pine (20)	Blue spruce (6.7)	Littleleaf linden (6.7)	(0)	15
	3	Blue spruce (50)	Green ash (11.5)	Pine (7.7)	Cottonwood/poplar (7.7)	Quaking aspen (7.7)	26
	4	Cottonwood/poplar (52.1)	Ponderosa/Austrian pine (16.7)	Blue spruce (12.5)	Common chokecherry (8.3)	Crabapple (4.2)	48
	5	Cottonwood/poplar (44)	Honeylocust (10)	Crabapple (10)	Green ash (8)	Fir (6)	50
	6	Ponderosa/Austrian pine (32.2)	Crabapple (14.8)	Honeylocust (7.8)	Spruce (7.8)	Green ash (6.1)	115
	7	Green ash (31.9)	Blue spruce (23.4)	Buckeye (14.9)	Juniper species (10.6)	Crabapple (6.4)	47
	8	Ponderosa/Austrian pine (22.2)	Fruit (18.5)	Blue spruce (14.8)	Green ash (11.1)	Honeylocust (11.1)	27
	9	Blue spruce (56.3)	Ponderosa/Austrian pine (43.8)	(0)	(0)	(0)	16
	10	Ponderosa/Austrian pine (47.9)	Cottonwood/poplar (12.7)	Green ash (11.3)	Fruit (8.5)	Honeylocust (5.6)	71
	11	Blue spruce (96.3)	Hackberry (3.7)	(0)	(0)	(0)	27
	12	Ponderosa/Austrian pine (35.1)	Juniper species (17.4)	Locust (9.1)	Blue spruce (7.4)	Honeylocust (6.8)	339
	13	Blue spruce (28.4)	Siberian elm (28.4)	Ponderosa/Austrian pine (14.9)	Russian olive (13)	Littleleaf linden (3.8)	208
	14	Blue spruce (19.7)	Willow (18)	Cottonwood/poplar (13.7)	Fruit (12)	Ponderosa/Austrian pine (7.7)	183
	15	Blue spruce (41.2)	Green ash (11.8)	Honeylocust (11.8)	Common chokecherry (11.8)	Maple (5.9)	17
	16	Cottonwood/poplar (43.5)	Willow (20.6)	Blue spruce (4.9)	Common chokecherry (3.5)	Green ash (3)	971
	17	Ponderosa/Austrian pine (29.5)	Siberian elm (14.1)	Blue spruce (13.6)	Cottonwood/poplar (13.1)	Crabapple (4.3)	2755
	18	Cottonwood/poplar (33.8)	Blue spruce (27.7)	Ponderosa/Austrian pine (15.3)	Pinyon pine (5.4)	Siberian elm (3.3)	1060
	19	Blue spruce (25.3)	Green ash (20.3)	Cottonwood/poplar (13.7)	Ponderosa/Austrian pine (11.4)	Russian olive (9.3)	605
	20	Blue spruce (59.9)	Juniper species (10.6)	Cottonwood/poplar (4.9)	Ponderosa/Austrian pine (4.6)	Common chokecherry (2.3)	1083
	21	Ponderosa/Austrian pine (42.9)	Cottonwood/poplar (25.7)	Crabapple (17.1)	Quaking aspen (8.6)	Kentucky coffee tree (5.7)	35
	Citywide	Blue spruce (22.5)	Ponderosa/Austrian pine (18.2)	Cottonwood/poplar (17.6)	Siberian elm (7.2)	Green ash (4.8)	8103
Street	1	Cottonwood/poplar (27.3)	Siberian elm (19.4)	Green ash (10.3)	Honeylocust (5.7)	Boxelder maple (4.9)	5298
	2	Honeylocust (14.1)	Cottonwood/poplar (13.5)	Green ash (12.6)	Siberian elm (9.8)	Boxelder maple (5.8)	1300
	3	Cottonwood/poplar (17.9)	Siberian elm (13.7)	Green ash (11.3)	Honeylocust (9)	Blue spruce (5.8)	2309
	Citywide	Cottonwood/poplar (22.9)	Siberian elm (16.5)	Green ash (10.9)	Honeylocust (7.8)	Boxelder maple (4.7)	8907
All	Total	Cottonwood/poplar (20.4)	Blue spruce (12.8)	Siberian elm (12.1)	Ponderosa/Austrian pine (10.1)	Green ash (8)	17010

DIVERSITY

Using Simpson's diversity index number (*C*) denotes the probability that two trees, chosen at random, will be of the same species; the lower the number, the more diverse the population (Simpson 1949). For example, C=0.10 can be interpreted as having the equivalent of 10 species evenly distributed. Twenty species evenly distributed would have an index value of 0.05, equivalent to each species representing about 5% of the population. Cheyenne's park and street trees have a diversity index of 0.13 and 0.11, respectively, indicating adequate diversity given the climate restrictions on plants. Diversity could be increased with new plantings as the extensive population of Cottonwoods and Siberian elms along streets age and require removal.

SPECIES IMPORTANCE

Importance values are particularly meaningful to managers because they suggest a community's reliance on the functional capacity of particular species. In other words, importance value (IV) provides meaningful interpretation with respect to the degree a city might depend on particular urban trees insofar as their environmental benefits are concerned. This evaluation takes into account not only total numbers, but their canopy cover, leaf area and spatial distribution (frequency), providing a useful comparison to the total population distribution.

As a mean of four relative values, importance values (IVs), in theory, can range between 0 and 100; where an IV of 100 suggests total reliance on one species and an IV of 0 suggests no reliance. The 18 species listed in Table 4 constituted 90% of the municipal tree population in Cheyenne, 96% of the leaf area, and 92% of the canopy cover. The remaining 40 species combined accounted for only 10% of the trees, 4% of the leaf area and 8% of the canopy cover. Importance values ranged from 0.5 for Pinyon pine (*Pinus edulis*) to 31.8 for Cottonwood.

Table 4. Importance Values (IV) calculated as the mean of tree numbers, leaf area, and canopy cover for the most abundant tree species.

Species	Number of trees	% of Total Trees	Leaf Area (ft2)	% of Total Leaf Area	Canopy Cover (ft2)	% of Total Canopy Cover	IV
Cottonwood/poplar	3,468	20.4	15,302,670	35.4	3,686,948	39.6	31.8
Blue spruce	2,180	12.8	4,567,166	10.6	599,962	6.4	9.9
Siberian elm	2,056	12.1	7,945,677	18.4	1,246,500	13.4	14.6
Ponderosa/Austrian pine	1,710	10.1	2,224,613	5.2	382,552	4.1	6.4
Green ash	1,358	8.0	3,922,767	9.1	753,908	8.1	8.4
Honeylocust	787	4.6	2,101,930	4.9	520,496	5.6	5.0
Crabapple	545	3.2	227,101	0.5	88,994	1.0	1.6
Boxelder maple	468	2.8	1,157,009	2.7	287,818	3.1	2.8
Juniper species	439	2.6	54,883	0.1	13,685	0.1	1.0
Willow	357	2.1	1,096,991	2.5	259,599	2.8	2.5
Common chokecherry	316	1.9	96,998	0.2	26,384	0.3	0.8
Pine	300	1.8	113,312	0.3	18,063	0.2	0.7
American elm	276	1.6	1,036,915	2.4	280,217	3.0	2.3
Quaking aspen	269	1.6	55,636	0.1	14,630	0.2	0.6
Pinyon pine	231	1.4	21,987	0.1	7,201	0.1	0.5
Russian olive	210	1.2	112,788	0.3	37,519	0.4	0.6
Hackberry	197	1.2	574,948	1.3	116,835	1.3	1.2
Silver maple	194	1.1	976,351	2.3	206,146	2.2	1.9
Other trees	1,649	9.7	1,594,623	3.7	772,453	8.3	7.2
Total City	17,010	100.0	43,184,363	100.0	9,319,909	100.0	100.0

Cottonwoods account for about one-fifth of all trees (3,468), but reliance on this species for benefit production is much higher than tree numbers alone indicate. The importance values indicate that Cheyenne is heavily reliant upon two species – Cottonwood and Siberian elm – for many of the environmental benefits associated with municipal trees. Cottonwoods “grow” over one-third of all the leaf area and nearly 40% of the canopy cover. In contrast, Ponderosa pine accounts for a relatively small percentage of total leaf area (5.2%) and canopy cover (4.1%) despite being among the most abundant trees.

STREET TREES PER CAPITA

Calculations of street trees per capita are important in determining how well forested a city is. The more residents and greater housing density a city possesses, the more need for trees to provide benefits. Assuming Cheyenne's human population is 53,011 (U.S. Census Bureau 2002), there is about one public tree for every three residents. Cheyenne's ratio of street trees per capita is 0.17, about half of the mean ratio of 0.37 reported for 22 U.S. street tree populations (McPherson and Rowntree 1989).

STOCKING LEVEL

There were approximately 15,200 street tree planting sites in Cheyenne and about 6,300 were estimated to be vacant (Table 5). Hence, 59% of all planting sites were filled with trees. Sites available for small trees (<25 ft tall) predominated, but medium trees (25-40 ft) could be planted in over 40% of the locations. Only two empty basins were available for large-stature (>40 ft) trees. Residential areas south of Pershing in older, more established areas of town account for

Table 5. Available planting spaces based on observed empty basins.

Street ROW Area	# of "empty basins"	% of area unplanted	% available as tree size Small	Medium	Large
Res. S. of Pershing	3,327.0	38.6	55.2	44.8	-
Downtown	952.0	42.3	58.0	42.0	-
Res. N. of Pershing	2,008.0	46.5	52.7	47.2	0.1

the majority of available planting spaces. Although the residential areas north of Pershing require fewer trees, the area has proportionately more unplanted space (46.5%) compared to south of

Pershing neighborhoods (38.6%). It should be noted that beginning in the 1960s, Cheyenne's newer residential neighborhoods in this area no longer incorporated a planting strip between the street and sidewalk. This resulted in an overall decline in street tree numbers and increased private trees on city lots.

City parks are fully stocked. When planting space become available through tree removal, they are systematically re-planted. Newer parks are well stocked with young trees that are provided the appropriate space in which to reach mature size.

AGE STRUCTURE

The distribution of ages within a tree population influences present and future costs as well as the flow of benefits. An uneven-aged population allows managers to allocate annual maintenance costs uniformly over many years and assure continuity in overall tree canopy cover. 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 all public trees in Cheyenne differed from the ideal only in having slightly fewer numbers of mature or older trees and almost 12% more newly outplanted trees (Figure 1). The pattern was similar for the street tree population except for an apparent gap in tree planting 12 –20 years ago.

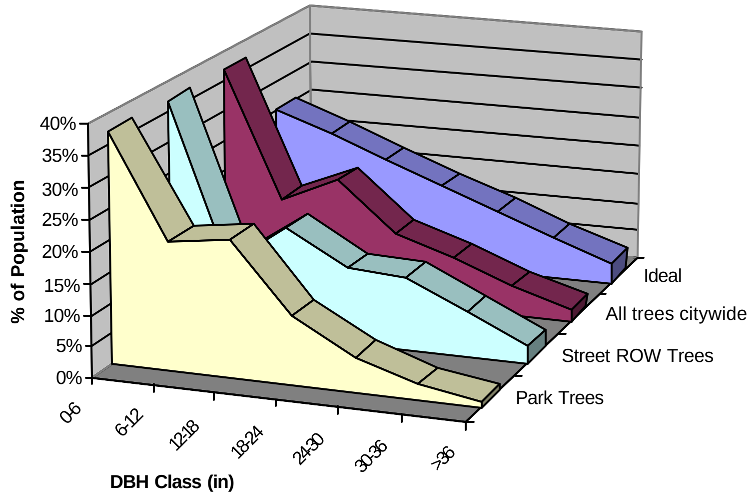
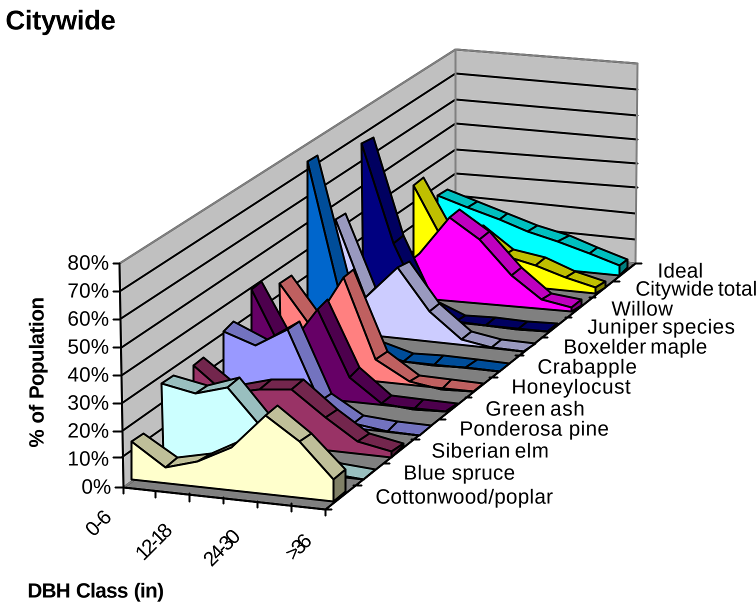
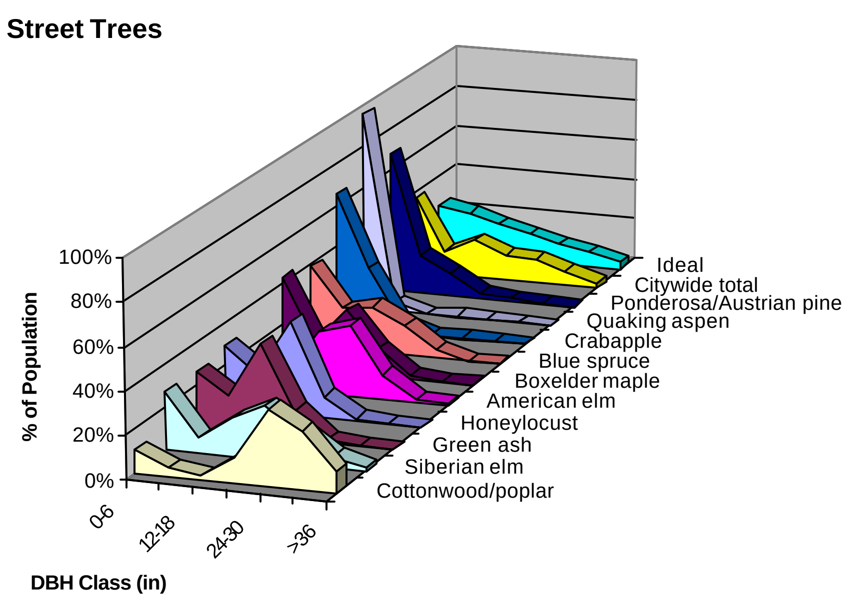


Figure 1. Ideal relative age distribution shown with Cheyenne's different street tree populations.

In parks, only mature tree numbers were less than ideal, but this scarcity of older trees was explained by the history of park development in the city. Park acreage has increased over the past 50 years as Cheyenne has grown. Newly annexed parkland is typically open grassland that is predominantly treeless. Continued consistent UFD planning and planting efforts for these new annexations are demonstrated by the number of younger trees present in the parks. These trees (with <24 in dbh) meet or exceed ideal tree numbers, but because tree establishment is more challenging given Cheyenne's climatic conditions, planting greater than "ideal" numbers of new trees is necessary. This increase in new plantings in both park and residential areas may also assist Cheyenne in maintaining a flow of benefits that could otherwise drop due to a gap in street tree planting that appears to have occurred between 12 and 20 years ago.

Age curves for different tree species help explain their relative importance and suggest how tree management needs may change as these species grow older. Figure 2 shows the importance of understanding relative age at different scales. Cottonwood and Siberian elm exhibited largely mature populations. These trees have provided benefits over a long period of time, and because of their size association with leaf area, are particularly important. The intensity of newer plantings of small-stature trees -- juniper (*Juniper sp.*) and crabapple (*Malus sp.*) -- likely will





not provide the level of benefits larger species afford.

Figure 2. Relative age distribution for Cheyenne's 10 most abundant trees citywide and for street trees.

Due predominantly to park tree plantings by the UFD, young populations of large-growing trees, including Blue spruce, Siberian elm, Ponderosa pine, Green ash, and Honeylocust, will contribute to a stream of future benefits as they mature. However, species selection and planting along Cheyenne's streets are of concern. As Figure 2 shows, Quaking aspen (*Populus tremuloides*) were being planted in increasing numbers by homeowners. Typically, aspen are weak-wooded, short-lived and require more water than many other species. They may grow rapidly to a medium size, but produce significantly less leaf area and fewer benefits than similar-sized species.

With the exception of Cottonwood, Siberian and American elms (*Ulmus americana*), there were few large species being planted along residential streets. Like aspen, Cottonwood and Siberian elm grow rapidly and tend to be weak-wooded. They produce an excellent stream of benefits for the city, but are better planted in parks rather than the space-restricted planting strips along Cheyenne streets.

TREE CONDITION

Tree condition indicates both how well trees are managed and their relative performance given site-specific conditions. Because of neglect and inconsistent management, street trees that are privately cared for are typically in poorer condition relative to those publicly managed (Bartenstein 1981). This held true in Cheyenne where the public park trees tended to be in better condition than the citizen-managed street trees (Figure 3 and Table 6). About 42% of city-maintained trees were in good condition compared to less than 10% maintained privately along streets. Similarly, there were over three times more poor and dead trees on streets than in parks.

Three-quarters of all trees on streets were in fair condition compared to slightly over half of the park trees.

Table 6. Condition of park and street tree population (%).

	Park					Street				
Species Name	Dead	Poor	Fair	Good	Excellent	Dead	Poor	Fair	Good	Excellent
Blue spruce	0.00	3.18	46.28	48.03	2.52	0.56	6.78	70.34	22.32	0.00
Common chokecherry	0.00	2.99	19.40	76.12	1.49	1.65	12.09	77.47	8.79	0.00
Cottonwood/poplar	0.00	5.52	65.10	28.74	0.63	0.29	19.47	73.84	6.34	0.05
Crabapple	0.00	3.99	44.20	51.09	0.72	0.37	4.83	79.55	15.24	0.00
Green ash	0.00	9.28	39.18	50.77	0.77	0.21	17.94	73.92	7.94	0.00
Hackberry	0.00	8.54	53.66	37.80	0.00	0.00	8.70	72.17	19.13	0.00
Honeylocust	0.00	7.29	34.38	58.33	0.00	0.43	9.71	75.65	13.77	0.43
Juniper species	0.00	4.20	62.24	33.57	0.00	0.00	5.23	68.63	26.14	0.00
Pine	0.00	4.76	29.52	58.10	7.62	0.00	4.62	80.51	14.87	0.00
Pinyon pine	0.00	5.41	51.35	43.24	0.00	0.00	5.00	84.17	10.83	0.00
Ponderosa/Austrian pine	0.00	1.76	37.62	60.35	0.27	0.86	9.48	68.53	21.12	0.00
Siberian elm	0.00	12.67	82.36	4.97	0.00	0.27	24.80	73.23	1.70	0.00
Park/Street Total	0.02	5.73	52.12	41.21	0.93	0.39	16.53	73.40	9.60	0.08
Citywide Total	0.22	11.38	63.26	24.66	0.48	0.22	11.38	63.26	24.66	0.48

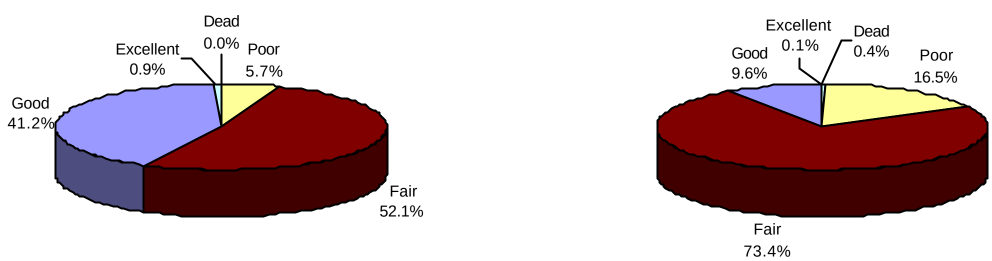


Figure 3. Citywide distribution of city-maintained park trees and privately maintained street trees.

The relative performance index (RPI) of each species provides an indication of their suitability to local growing conditions, as well as their performance. It is calculated for each species by dividing its proportion of all trees rated as good or excellent by the percentage of all trees rated as good or excellent. For example, Hackberry's relative performance is 1.07 because 26.9% were good or excellent compared to 25.15% of all trees citywide rated good or excellent (0.269/0.2515 = 1.07). Species with RPIs greater than 1.0 have proportionately more individuals classified as good or excellent (Table 7). Species with larger percentages of trees in good condition are likely to be better adapted to Cheyenne's climate, requiring fewer inputs of money and management.

Abundant species rated as having the best performance, overall, were Ponderosa/Austrian pine, Blue spruce, Chokecherry (*Prunus virginiana*), Crabapple species, Juniper species, Pine species, Hackberry, and Pinyon pine. These species were widely adapted to growing conditions throughout the city. Predominant species with the lowest performance included Green ash, Honeylocust, Cottonwood, and Siberian elm. Citywide, the majority of these species appeared to perform well, but closer examination of their relative performance by location showed that the higher performance of species depended on the generally better condition exemplified by the UFD managed park trees (Table 7). With the exception of Siberian elm, all species performed above the 1.0 level. The reverse was true for the street species where only Juniper exceeded 1.0. This discrepancy between performance levels of the same species suggests that tree management and maintenance – consistency of care, pruning and irrigation to maintain tree health – differs significantly between the city-managed park trees and the privately maintained street tree population.

Table 7. Relative performance index (RPI) for predominant Cheyenne trees in Parks, Streets, and Citywide.

Species Name	Park RPI	ROW RPI	Citywide RPI
Ponderosa/Austrian pine	2.45	0.86	2.23
Blue spruce	1.95	0.90	1.78
Common chokecherry	3.09	0.36	1.51
Crabapple	2.07	0.62	1.35
Juniper species	1.36	1.06	1.26
Pine	2.36	0.60	1.22
Hackberry	1.53	0.78	1.09
Pinyon pine	1.75	0.44	1.07
Green ash	2.06	0.32	0.82
Honeylocust	2.37	0.56	0.78
Cottonwood/poplar	1.17	0.26	0.63
Siberian elm	0.20	0.07	0.11

Appendix C lists the RPI for all species included in the 1992 inventory. Although less abundant, other high performing species include Littleleaf linden (*Tilia cordata*), Red oak (*Quercus rubra*), Eastern red cedar (*Juniperus virginiana*), and Cherry (*Prunus sp.*). The Linden and Oak are particularly important because they represent larger growing trees that could contribute to increasing future benefits. Few of these trees are fully mature, yet the potential they show for contributing to canopy cover and leaf area is noteworthy. For example, In the 12-18 inch DBH classes Linden and Oak in the 12-18 inch dbh size class produce 50 and 57% more leaf area, respectively, than same-sized Cottonwoods. There are additional large-growing species well-suited to Cheyenne's climate that can be planted to replace the aging Cottonwood and Siberian elm population. These include American linden (*Tilia americana*), Hackberry, Bur Oak (*Quercus macrocarpa*), and perhaps new Dutch elm disease resistant cultivars of American elm, all species the Cheyenne UFD currently encourages homeowners to plant.

TREE CANOPY

The combined street and park tree canopy was estimated at over 9 million ft^2 (86.6 ha). Given a city area of 22.87 mi^2 (59.23 km^2), canopy specific to street trees alone covered over 6 million acres (~57.0 ha) and shaded 1.82% of Cheyenne's paved streets. Park trees shaded an additional 0.7 % of streets. These calculations assumed that 24% of all tree canopy cover was shading street surfaces, there were 339.7 miles of street, and the average curb-to-curb distance was 45 ft (Maco and McPherson 2002). Research in Davis CA showed that by shading asphalt surfaces and parked vehicles the trees reduce hydrocarbon emissions from gasoline that evaporates out of leaky fuel tanks and worn hoses (Scott et al. 1999). These evaporative emissions are a principal component of smog, and parked vehicles are a primary source.

The additional benefits of shade provided by canopy cover include offsetting pavement management costs by protecting paving from weathering. The asphalt paving on streets contains stone aggregate in an oil binder. Tree shade lowers the street surface temperature and reduces the heating and volatilization of the oil. As a result, the aggregate remains protected for a longer period by the oil binder. When unprotected, vehicles loosen the aggregate and much like sandpaper, the loose aggregate grinds down the pavement (Brusca 1998).

LOCATION & OTHER FEATURES

The majority of the 8,901 street trees in Cheyenne were located in planting strips. Our sample estimated that 74% of these trees were adjacent to single family residential land uses and others were on commercial/industrial (16%), multi-home residential (5%), and other land uses (4%, institutional, vacant, or agricultural use). The 8,103 publicly managed park trees included an estimated 20.7% on golf courses, 13.5% in cemeteries, 5.4% on street islands, medians and triangles, and 60.5% in parks.

The correct placement of trees – choosing the right tree for the right location – can decrease the costs associated with the care and maintenance. Properly placed trees have adequate space to grow with reduced potential for infrastructure (e.g., sidewalks), utility line or visibility conflicts. Table 8 shows the number of trees in each of six placement categories based on a tree's suitability and appropriateness for its location. Proximity to utilities, sidewalks and structures plus the tree's purpose and visual impact were used for rating. With nearly 85% of the trees located in fair or better locations, the majority of trees were well placed in Cheyenne. Tree placement tended to be poorer along streets, where trees were confined to planting strips, compared to park tree placement. About 24% of street trees were in locations rated poor or worse. Over half (53%) of these 2,112 trees were Cottonwood and Siberian elm.

Table 8. Placement ratings for street and park trees (no. of trees).

Management	Liability	Very Poor	Poor	Fair	Good	Excellent
Street ROW	1	224	1,887	4,519	2,275	1
Parks	1	44	462	2,124	4,614	858
Citywide % of tot	0.01	1.58	13.81	39.05	40.50	5.05

MAINTENANCE NEEDS

Understanding species distribution, age structure, and tree condition may aid in determining proper pruning cycle length, but it is important to understand the actual pruning and maintenance needs of the city trees. Not only will this provide clues to whether or not the pruning is adequate, but what level of risk and liability is associated with the city's street tree population.

Citywide, 5,564 trees, or about 33% of the tree population, required maintenance in the form of removal, general or safety pruning (Fig. 4). Street trees accounted for nearly 80% of all trees requiring maintenance and park trees accounted for the remaining 20%. Nearly half of all street trees (4,410 or 49.5%) required maintenance, compared to only 14% of all park trees (1,154).

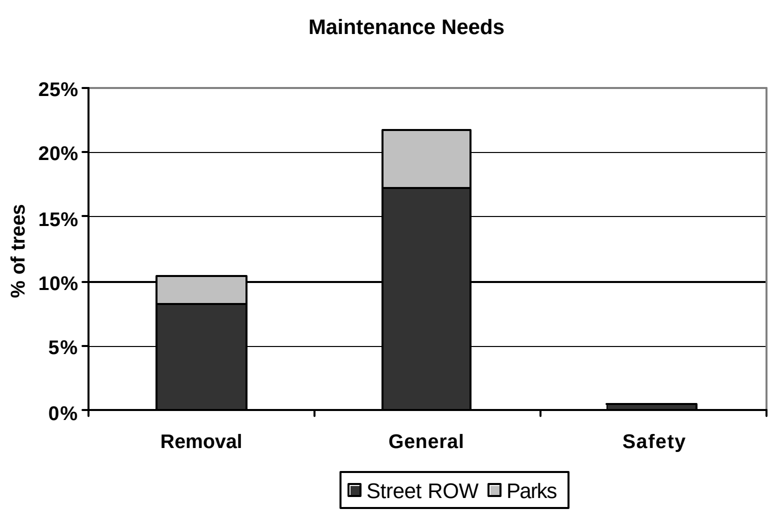


Figure 4. Percent of the total street and park tree population with maintenance needs.

General Pruning

A general pruning implies trees that are maintained to promote continued good health and performance. This type of pruning includes crown cleaning and thinning, removal of epicormic sprouts, and pruning for clearance or to maintain the structural integrity of the tree. Overall, 3,693 (22%) of the trees needed general pruning. Privately maintained street trees alone accounted for 79% of the trees needing pruning (2,930 trees) with the remaining 21% (763 trees) being park trees. The park tree population was markedly better maintained than street trees.

Safety and Removals

A safety prune implies remedy for hazardous tree conditions. Trees requiring removal indicate severe problems, although these are not necessarily related to safety hazards. Numbers may simply reflect dead or dying newly planted trees, or they may reflect unmanageable tree defects and hazards. Regardless, trees classified as needing removal and replacement detract from aesthetic appearance at best, and represent substantial costs or public safety hazards at worst. Over three-quarters of the 1,480 trees along Cheyenne streets requiring removal or safety pruning consisted of these five species: Siberian elm (29.4%), Cottonwood (24%), Boxelder maple (11.4%), Green ash (8.3%), and Blue spruce (3.5%).

Park trees determined to need removal (373) or safety pruning (18) were nearly four-fold fewer than street trees, with the top five species accounting for 67% of all trees in this category: Siberian elm (23%), Cottonwood (19%), Blue spruce (12%), Green ash (*Fraxinus pennsylvanica*) (7%), and Ponderosa pine (6%). Since the 1992 inventory, the UFD has established a programmed park tree maintenance program, systematically pruning and maintaining park trees. Program accomplishments are shown in Table 9.

Table 9. Park tree maintenance accomplishments since the 1992 inventory.

Maintenance Accomplishments, 1992-2002				
Year	Pruned	Removed	Purchased & Planted	Spaded & Replanted
1992	n/a	n/a	350 *	300
1993	1100	n/a	75	200
1994	1000	n/a	75	200
1995	1500	25	140	n/a
1996	1200	20	300	200
1997	1500	12	190	100
1998	1500	70	660	160
1999	1361	125	275	99
2000	1217	48	281	46
2001	1454	135	163	156
2002	1041	235	538	160
Totals	12873	670	3047	1621

*110 cost-shared w/business

CHAPTER THREE—COSTS OF MANAGING CHEYENNE'S MUNICIPAL TREES

FISCAL YEAR 2001-2002 PROGRAM EXPENDITURES

Costs of Managing Public Trees

Costs were based on a review of expenditures during fiscal year 2001 and adjusted to reflect per tree expenditures for the 1992 municipal tree inventory. The 2001 operating budget for the Cheyenne Urban Forest Division Tree Program was $469,207, with no abnormal expenditures recorded during the year (Olson and Overstreet 2002). This amount represented 0.67% of the city's total 2001 operating budget ($69,889,724). An additional $5,000 was spent on tree-related matters by other city departments for storm cleanup. Overall, $474,207, or $8.95 per capita, was spent on management of Cheyenne's municipal urban forest. The 2002 estimated municipal tree total was 24,600 (Olson and Overstreet 2002) with expenditures per tree of $19.28 (Table 10). The per tree expenditure was similar to the 1997 mean value of $19 per tree reported for 256 California cities (Thompson and Ahern 2000) and a third less than the $29.91 per tree spent in nearby Fort Collins, Colorado (McPherson et al. 2004). Assuming the same per tree expenditure for the 17,010 trees listed in the 1992 municipal tree inventory, we estimated total municipal tree expenditures at $327,897 (17,010 x $19.28) or $6.19 per capita for the 1992 inventory. Forestry Division expenditures fell into three categories: tree planting and establishment, mature tree care, and administration.

Table 10. Cheyenne annual expenditures in 2001.

Program Expenditures	City
Pruning	$122,460
Planting	$66,400
Removals	$33,750
Inspection	$11,000
Pest & Disease	$7,300
Administration/Other	$91,800
Irrigation	$136,497
Total Program Expenditures	$469,207
Non-Program Expenditures	
Storm/Litter Clean-Up	$5,000
Grant Total Expenditures	$474,207

Tree Planting and Establishment

The production of quality nursery stock, its subsequent planting, and follow-up care are critical to perpetuation of a healthy urban forest for Cheyenne. Trees not produced in the city nursery are obtained from reputable growers. Typically, homeowners obtain trees from local nurseries. Over the past five years, the UFD planted and established an average of about 500 park trees each year, 90% at new sites and 10% as replacements for removed trees. Costs are typically about $475 per tree, including $200 for a purchased tree, $83 for planting, and $192 for establishment watering. These activities consume 14% of the 2001 tree program budget, or $66,400. Future planting costs should be significantly reduced because the UFD is switching from planting ball-and-burlap (B & B) trees to bareroot (BR), reducing tree cost by 75% to $50.

Approximately 1,100 small trees are pruned annually for structure and form. The majority of these are recently planted trees receiving a training prune ($8/tree); the remainder are small tree prunings at a cost of $28/tree (Overstreet 2004).

About 1,000 street trees and 1,800 park trees are watered an average of 16 times annually. About 85% of the water is drafted from Absarraca Lake. At a cost of $2.40 per thousand gallons, the use of this treated wastewater rather than the potable city system water represents a significant savings to the city, particularly during drought years. The wastewater costs the city about $0.05 per tree per week, and the water truck costs $3 per tree per watering. Total annual watering costs constitute a budget expenditure of $136,497 (29.8%) or $48.75 per tree. This amount varies significantly depending upon annual precipitation. Irrigation costs over the past 5 years have been higher than normal due to drought. With increased precipitation this year, irrigation costs could be significantly lower.

Mature Tree Care

Cheyenne's urban forest contains many mature and old trees so it is not surprising that about 36% ($167,200) of the 2001 tree program's budget was spent keeping these trees healthy and safe. Pruning, tree removal, and inspection accounted for most of this amount. Approximately $122,460 was spent for programmed pruning in the parks. The Division removes about 140 trees each year (based on the past 5 years) at a cost of $33,750 (includes stump removal).

Mature tree care for street trees is dependent upon adjacent property owners. Inspection time for answering service requests, public education, and plan review adds up to $11,000 annually. If the Division determines that a street tree needs pruning or removal, the property owner is notified. After 30 days, the tree is re-inspected and if work has not been completed the property owner is served a second notice. Subsequent non-compliance results in the Division putting the work out to bid, selecting the low bid, and then billing the property owner. For low- and moderate-income homeowners, Community Development Block Grant (HUD) funds are available to provide financial assistance for removing trees that are hazardous along street rights-of-way and planting new trees.

Pest infestations can pose a serious threat to the health and survival of susceptible tree species, and drip from insects is a nuisance to residents. The 2001 pest and disease control expenditures totaled $7,300 for treatments to control spider mites, ash borers, elm scale, and other pests.

Cleanup after storms occurs on a periodic basis. Approximately $5,000 was spent in 2001 and no more than that sum is typically spent annually.

Administration

Approximately 19% of all program expenditures were for administration, totaling $91,800. This item accounted for salaries and benefits of supervisory staff that performed planning and management functions, as well as contract development and supervision.

Chapter Four—Benefits of Cheyenne Municipal Trees

INTRODUCTION

Estimates of benefits and costs are initial approximations—as some benefits and costs are intangible or difficult to quantify (e.g., impacts on psychological health, crime, and violence). Also, limited knowledge about the physical processes at work and their interactions make estimates imprecise (e.g., fate of air pollutants trapped by trees and then washed to the ground by rainfall). Tree growth and mortality rates are highly variable and benefits and costs depend on the specific conditions at the site (e.g., tree species, growing conditions, maintenance practices). Therefore, this method of quantification was not intended to account for every benefit or penny. Rather, this approach was meant to be a general accounting of the benefits produced by municipal trees in Cheyenne; an accounting with an accepted degree of uncertainty that can nonetheless, provide a platform on which decisions can be made (Maco 2003). Methods used to quantify and price these benefits are described in Appendix B.

ENERGY SAVINGS

Trees modify climate and conserve building-energy use in three principal ways:

1. Shading—reduces the amount of radiant energy absorbed and stored by built surfaces.
2. Transpiration—converts moisture to water vapor and thus cools by using solar energy that would otherwise result in heating of the air.
3. Wind speed reduction—reduces the infiltration of outside air into interior spaces and conductive heat loss where thermal conductivity is relatively high (e.g., glass windows) (Simpson 1998).

Trees and other greenspace within individual building sites may lower air temperatures 5°F (3°C) compared to outside the greenspace (Chandler 1965). At the larger scale of urban climate (6 miles or 10 km square), temperature differences of more than 9°F (5°C) have been observed between city centers and more vegetated suburban areas (Akbari et al. 1992). The relative importance of these effects depends on the size and configuration of trees and other landscape elements (McPherson 1993). Tree spacing, crown spread, and vertical distribution of leaf area influence the transport of cool air and pollutants along streets and out of urban canyons. Appendix B provides additional information on specific areas of contribution trees make toward energy savings.

ELECTRICITY AND NATURAL GAS RESULTS

Electricity and natural gas saved annually in Cheyenne from both shading and climate effects totaled 1,175 MWh and 21,370 Mbtu, respectively, for a total retail savings of $186,986 (Table 1) or a citywide average of $10.99/tree. Savings per tree for park trees were smaller than for street trees, averaging $7.51/tree compared to $14.15/tree for street trees, reflecting the fact that park trees provide only climate benefits, while street trees provide both shade and climate benefits.

Table 11. Net annual energy savings produced by Cheyenne municipal trees.

Tree Species	Electricity (MWh)	Natural Gas (Mbtu)	Total ($)	% of Total $	Avg. $/tree
Cottonwood/poplar	481	8,254	74,459	39.8	21.47
American elm	35	590	5,387	2.9	23.84
Silver maple	23	387	3,566	1.9	19.59
Hackberry	18	320	2,815	1.5	14.29
Siberian elm	183	3,125	28,270	15.1	13.75
Willow	29	616	4,940	2.6	14.93
Honeylocust	67	1,217	10,670	5.7	13.56
Boxelder maple	39	665	6,019	3.2	14.50
Green ash	99	1,834	15,867	8.5	11.68
Birch	4	69	595	0.3	6.39
Crabapple	13	287	2,257	1.2	4.14
Blue spruce	68	1,493	11,919	6.4	5.47
Ponderosa/Austrian pir	52	1,197	9,282	5.0	5.43
Fir	1	20	151	0.1	1.73
Russian olive	2	48	375	0.2	2.47
Common chokecherry	2	55	422	0.2	1.33
Quaking aspen	2	41	326	0.2	1.40
Pinyon pine	1	19	152	0.1	0.66
Pine	2	47	364	0.2	1.21
Juniper species	2	44	337	0.2	0.77
Other Street Trees	35	631	5,542	3.0	5.73
Other Park Trees	19	411	3,271	1.7	4.44
Street Tree Total	827	13,718	126,116	67.4	14.16
Park Tree Total	348	7,652	60,870	32.6	7.51
Grand Total	1,175	21,370	186,986	100.0	10.99

In general, larger trees produced larger benefits. Differences in benefits between life forms (evergreen, deciduous, conifer) were dramatic, with large deciduous street trees producing nearly six times the benefit of large coniferous street trees (Table 12). Large park conifers produced roughly half the energy benefits of the large park deciduous trees. Energy benefits associated with conifers adjacent to homes were lower because the detrimental effect of their winter shade on heating costs outweighed their wind reduction benefit. Conversely, the higher park benefit illustrates the benefit of wind speed reduction by non-deciduous species not associated with residential homes.

Table 12. Average per tree energy benefit ($) by tree type.

Tree Type	Street	Park
Lg. Deciduous	18.10	11.84
Med. Deciduous	2.91	2.29
Sm. Deciduous	3.90	2.44
Lg. Conifer	3.12	5.41
Sm. Conifer	0.56	0.86
Citywide Total	14.16	7.51

ATMOSPHERIC CARBON DIOXIDE REDUCTIONS

Urban forests can reduce atmospheric CO_2 in two ways:

1. Trees directly sequester CO_2 as woody and foliar biomass while they grow.
2. Trees near buildings can reduce the demand for heating and air conditioning, thereby reducing emissions associated with electric power production.

On the other hand, CO_2 is released by vehicles, chain saws, chippers, and other equipment during the process of planting and maintaining trees. Eventually, all trees die and most of the CO_2 that has accumulated in their woody biomass is released into the atmosphere through decomposition unless recycled.

As Table 13 shows, the amount of CO_2 benefits produced is dependent on species present and their age. Citywide, park tree reduction of energy plant CO_2 emissions and net sequestration rates were equivalent at 332 tons each or 664 total tons at a value of $9,960. Cottonwood (31.6%) and

Table 13. Net CO_2 reductions of Cheyenne street and park trees.

Tree Species	Total lb	Total $	% of Total $	Avg. $/tree
Cottonwood/poplar	1,423,723	10,678	36.7	3.08
American elm	91,526	686	2.4	3.04
Silver maple	77,019	578	2.0	3.17
Hackberry	43,206	324	1.1	1.64
Siberian elm	689,515	5,171	17.7	2.52
Willow	84,624	635	2.2	1.92
Honeylocust	175,748	1,318	4.5	1.67
Boxelder maple	107,560	807	2.8	1.94
Green ash	318,873	2,392	8.2	1.76
Birch	12,268	92	0.3	0.99
Crabapple	39,034	293	1.0	0.54
Blue spruce	471,056	3,533	12.1	1.62
Ponderosa/Austrian pine	136,930	1,027	3.5	0.60
Fir	5,050	38	0.1	0.44
Russian olive	6,829	51	0.2	0.34
Common chokecherry	7,096	53	0.2	0.17
Quaking aspen	6,623	50	0.2	0.21
Pinyon pine	2,135	16	0.1	0.07
Pine	5,843	44	0.2	0.15
Juniper species	4,878	37	0.1	0.08
Other Street Trees	108,193	811	2.8	0.84
Other Park Trees	65,489	491	1.7	0.67
Street Tree Total	2,556,671	19,175	65.8	2.15
Park Tree Total	1,327,957	9,960	34.2	1.23
Grand Total	3,884,628	29,135	100.0	1.71

Blue spruce (30.1%) accounted for over 61% of the CO_2 benefits produced by park trees. Park tree species with the highest per tree savings were Cottonwood ($2.20), Willow ($1.92), Siberian elm ($1.76), Blue spruce ($1.64), and Hackberry ($0.80). Street trees had an annual net sequestration rate of approximately 491 tons and reduced emissions by another 788 tons for a total savings of $19,175. The combination of these park and street tree savings was valued at $29,135 annually. On average, CO_2 benefits for street trees were 75% higher than park trees on a per tree basis.

Citywide, the total reduced CO_2 emissions (1120 t) were 36% greater than total sequestered CO_2 (823 t). Avoided emissions are extremely important in Cheyenne because fossil fuels are the primary energy source. These fuels have a relatively high CO_2 emission factor. Further, Cheyenne's climate is extreme in winter due to low temperatures and high winds, resulting in higher heating loads compared to Fort Collins, Colorado, 45 miles south of Cheyenne and sheltered by the Rocky Mountains.

AIR QUALITY IMPROVEMENT

Urban trees provide air quality benefits 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 limiting building energy consumption
4. Releasing oxygen through photosynthesis
5. Transpiring water and shading surfaces, which lowers local air temperatures, thereby reducing ozone levels.

In the absence of the cooling effects of trees, higher air temperatures contribute to ozone formation. Most trees emit various biogenic volatile organic compounds (BVOCs) such as isoprenes and monoterpenes that can contribute to ozone formation. The ozone forming potential of different tree species varies considerably (Benjamin and Winer 1998). A computer simulation study for the Los Angeles basin found that increased tree planting of low BVOC emitting tree species would reduce ozone concentrations and exposure to ozone, while planting of medium- and high-emitters would increase overall ozone concentrations (Taha 1996). High emitters of BVOCs (> 10 ug/g/hr) in Cheyenne are Cottonwood, Blue spruce, and Ponderosa/Austrian pine.

Deposition and Interception Result

Pollutant uptake by tree foliage (pollution deposition and particulate interception) in Cheyenne was 2.3 tons of combined uptake at a total value of $8,429 or $0.50/tree. Cottonwood alone accounted for 51% of this amount and street tree uptake was over two times the amount of park tree uptake. Ozone and small particulate matter (PM_{10}) represented 54% and 24% the largest savings associated with deposition and interception. The filtering of airborne dirt and dust particles is a noteworthy benefit to Cheyenne residents and one of the reasons trees and windbreaks were originally established on the prairie.

Avoided Pollutants and BVOC Emissions Result

Park trees emitted BVOC at a slightly higher rate than street trees, averaging 0.50 lbs/tree and 0.42 lbs/tree, respectively. This difference can be attributed to the larger size and number of high emitting conifers in the park population (4,019 conifers) compared to the street tree population (1,264 conifers). Cheyenne's highest emitters included Cottonwood (1.27 lbs/tree), Blue spruce (0.86 lbs/tree), Willow (0.86 lbs/tree) and Ponderosa/Austrian pine (0.36 lbs/tree). Essentially, all of Cheyenne's predominant tree species were higher emitting, but their effect was counteracted by the fact that trees near buildings reduce the demand for heating and air-conditioning. This reduction in demand results in less energy consumption, thereby avoiding the hydrocarbon emissions associated with the use of fossil fuels as a primary energy source. As a result, annual avoided pollutant emissions at power plants minus BVOC emissions totaled 3.1 tons for a benefit of $3,480 or over $0.20/tree.

Net Air Quality Improvement

Cheyenne's municipal forest produced annual air quality benefits valued at $11,909 ($0.70/tree) by removing 5.4 tons of pollutants from the atmosphere (Table 14). Net air quality savings were primarily due to pollutant uptake, particularly for street trees. Higher BVOC emissions for park trees cancelled out much of the pollutant uptake benefit, resulting in an average savings of only $0.02/tree compared to $1.32/tree for street trees. Low deposition rates coupled with higher BVOC emissions resulted in a net cost for three conifers – Blue spruce ($1.00/tree), Fir (Abies species, $0.25/tree) and Pine ($0.03/tree). Trees producing the greatest benefit included American elm ($3.31), Silver maple ($2.47), Siberian elm ($1.94), and Hackberry ($1.75).

Table 14. Net air quality benefits for all street and park trees.

Tree Species	Total lb	Total $	% of Total $	Avg. $/tree
Cottonwood/poplar	3618	3347	28.1	0.97
American elm	525	747	6.3	3.31
Silver maple	326	450	3.8	2.47
Hackberry	246	344	2.9	1.75
Siberian elm	2775	3982	33.4	1.94
Willow	140	73	0.6	0.22
Honeylocust	942	1316	11.1	1.67
Boxelder maple	492	656	5.5	1.58
Green ash	1380	1940	16.3	1.43
Birch	46	62	0.5	0.66
Crabapple	176	251	2.1	0.46
Blue spruce	-844	-2171	-18.2	-1.00
Ponderosa/Austrian pine	276	156	1.3	0.09
Fir	-8	-22	-0.2	-0.25
Russian olive	31	47	0.4	0.31
Common chokecherry	34	49	0.4	0.16
Quaking aspen	19	24	0.2	0.10
Pinyon pine	6	6	0.0	0.02
Pine	3	-9	-0.1	-0.03
Juniper species	12	10	0.1	0.02
Other Street Trees	-98	380	3.2	0.39
Other Park Trees	-36	229	1.9	0.31
Street Tree Total	9363	11730	98.5	1.32
Park Tree Total	1375	179	1.5	0.02
Grand Total	10737	11909	100.0	0.70

STORM-WATER RUNOFF REDUCTIONS

Urban storm-water runoff is an increasing concern as a significant pathway for contaminants entering local streams, lakes and reservoirs. In effort to protect threatened fish and wildlife, storm-water management requirements are becoming increasingly broad, stringent, and costly; cost-effective means of mitigation are needed. Healthy urban trees can reduce the amount of runoff and pollutant loading in receiving waters in three primary ways:

1. Leaves and branch surfaces intercept and store rainfall, thereby reducing runoff volumes and delaying the onset of peak flows.
2. Root growth and decomposition increase the capacity and rate of soil infiltration by rainfall and reduce overland flow.
3. Tree canopies reduce soil erosion and surface transport by diminishing the impact of raindrops on barren surfaces.

The ability of Cheyenne's municipal trees to intercept rain was estimated at 5,686,650 gallons (760,191 ft^3) annually (Table 15). The total value of this benefit to the city was $55,301 when all trees were considered. Street tree interception (498,143 ft^3) was 90% greater than park tree interception (262,048 ft^3). This difference is attributable to the larger amount of leaf surface area associated with the street tree population; where species accounting for more than 1% of the population had over 26.5 M ft^2 of leaf area compared to less than 17 M ft^2 in parks. Average per tree values for street trees ranged from $0.13 to $6.59, averaging $3.25, based on 334 gallons per tree intercepted. This average per tree value was low compared to Fort Collins, Colorado where an average annual benefit of $13.04/tree was returned. Cheyenne's trees, on average, had only 15% less leaf area and 12% more crown projection area than Fort Collins' trees; the more than three-fold difference between Cheyenne and Fort Collins in dollars saved does not reflect the rainfall interception capacity of Cheyenne's trees but is a function of the lower estimated price of rainfall intercepted and has a substantial influence on interception benefits. Prices are highly variable among cities and reflect local willingness to pay for storm-water management. Thus, if a community chooses to provide little funding for storm-water collection and treatment programs, the interception benefit is less.

Table 15. Annual storm-water reduction benefits of Cheyenne street and park trees by species.

Tree Species	Rainfall Intercept. (gal)	Total $	% of Total $	Avg. $/tree
Cottonwood/poplar	2,347,750	22,831	41.3	6.58
American elm	143,957	1,400	2.5	6.19
Silver maple	123,252	1,199	2.2	6.59
Hackberry	69,614	677	1.2	3.44
Siberian elm	945,476	9,194	16.6	4.47
Willow	151,565	1,474	2.7	4.45
Honeylocust	228,798	2,225	4.0	2.83
Boxelder maple	157,849	1,535	2.8	3.70
Green ash	460,063	4,474	8.1	3.29
Birch	9,763	95	0.2	1.02
Crabapple	35,316	343	0.6	0.63
Blue spruce	475,620	4,625	8.4	2.12
Ponderosa/Austrian pine	238,220	2,317	4.2	1.35
Fir	5,402	53	0.1	0.60
Russian olive	9,398	91	0.2	0.60
Common chokecherry	14,262	139	0.3	0.44
Quaking aspen	7,166	70	0.1	0.30
Pinyon pine	3,184	31	0.1	0.13
Pine	11,327	110	0.2	0.37
Juniper species	7,488	73	0.1	0.17
Other Street Trees	144,587	1,406	2.5	1.45
Other Park Trees	96,594	939	1.7	1.27
Street Tree Total	3,726,383	36,238	65.5	4.07
Park Tree Total	1,960,267	19,063	34.5	2.35
Grand Total	5,686,650	55,301	100.0	3.25

When averaged throughout the entire street tree population, certain species were much better at reducing storm-water runoff than others. Leaf type and area, branching pattern and bark, as well as tree size and shape all affected the amount of precipitation trees can intercept and hold to avoid direct runoff. Trees in Cheyenne such as Cottonwood, Silver maple, American and Siberian elm performed this function very well, while Pinyon and Juniper species were among the worst performers.

PROPERTY VALUES AND OTHER BENEFITS

The estimated total annual benefit associated with property value increase was approximately $403,000, or $24/tree on average (Table 16). This value was about half that for trees in Fort Collins, not surprising because median home prices greatly influence the average annual dollar savings and Fort Collins had nearly twice the median home price of Cheyenne. Street trees in Cheyenne were responsible for 56% of the $403,000 benefit. Generally, street trees are assumed to have a greater impact on property values than park trees; however, the proximity of multi-use parks and greenbelts may also contribute to an increase in property values of entire neighborhoods.

Table 16. Total annual increases in property value from Cheyenne street trees by species.

Tree Species	Total $	% of Total Tree	% of Total $	Avg. $/tree
Cottonwood/poplar	106,086	20.4	26.3	30.59
American elm	9,852	1.3	2.4	43.59
Silver maple	5,972	1.1	1.5	32.81
Hackberry	7,652	1.2	1.9	38.84
Siberian elm	61,938	12.1	15.4	30.13
Willow	8,764	1.9	2.2	26.48
Honeylocust	16,291	4.6	4.0	20.70
Boxelder maple	11,163	2.4	2.8	26.90
Green ash	29,727	8.0	7.4	21.89
Birch	779	0.5	0.2	8.37
Crabapple	8,092	3.2	2.0	14.85
Blue spruce	53,854	12.8	13.4	24.70
Ponderosa/Austrian pine	31,982	10.1	7.9	18.70
Fir	1,037	0.5	0.3	11.92
Russian olive	2,625	0.9	0.7	17.27
Common chokecherry	6,286	1.9	1.6	19.89
Quaking aspen	2,597	1.4	0.6	11.15
Pinyon pine	762	1.4	0.2	3.30
Pine	4,110	1.8	1.0	13.70
Juniper species	1,748	2.6	0.4	3.98
Other Street Trees	19,435	5.7	4.8	20.10
Other Park Trees	11,971	4.3	3.0	16.24
Street Tree Total	224,577	52.4	55.8	25.21
Park Tree Total	178,146	47.6	44.2	21.99
Grand Total	402,723	100.0	100.0	23.68

Tree species adding the largest amount of leaf area over the course of a year tend to produce the highest average annual benefit. American elm ($44/tree), and Hackberry ($39/tree) were on the high end, while Pinyon pine ($3/tree), Juniper species ($4/tree), Birch ($8/tree) and Quaking aspen ($11/tree) averaged the least benefits (Table 16). Large, fast-growing species tend to be associated with increased higher annual returns. Although species such as Quaking aspen may be considered fast growing, the higher mortality rate (shorter life span) coupled with lower leaf area and poorer condition negates their overall impact.

TOTAL ANNUAL NET BENEFITS AND BENEFIT-COST RATIO (BCR)

Total annual benefits produced by Cheyenne’s street and park trees were estimated to have a value of $686,000, about$40/tree and $13/resident. Street trees produced benefits valued at nearly $418,000 ($47/tree, $8/capita), while park tree benefits were valued at about $268,000 ($34/tree, $5/capita [Table 17]. The Cheyenne municipal forest returned $2.09 to the community for every $1 spent on their management. Street trees contributed $1.27 of this amount, with park trees contributing the remaining $0.82.

Table 17. Benefit-Cost summary with high and low estimates based on population standard error.

	Street			Park			All		
Benefit	Total ($)	$/capita	$/tree	Total ($)	$/capita	$/tree	Total ($)	$/capita	$/tree
Energy	126,116	2.38	14.16	60,870	1.15	7.51	186,986	3.53	10.99
CO2	19,175	0.36	2.15	9,960	0.19	1.23	29,135	0.55	1.71
Air Quality	11,730	0.22	1.32	179	0.00	0.02	11,909	0.22	0.70
Stormwater	36,238	0.68	4.07	19,063	0.36	2.35	55,301	1.04	3.25
Environmental Subtotal	193,259	3.65	21.70	90,072	1.70	11.12	283,331	5.34	16.66
Property Increase	224,372	4.23	25.19	178,351	3.36	22.41	402,723	7.60	23.68
Total benefits	417,631	7.88	46.89	268,423	5.06	33.52	686,054	12.94	40.33
Total costs							327,897	6.19	19.28
Net benefits							358,157	6.76	21.06
Benefit-cost ratio							2.09	2.09	2.09

Cheyenne municipal trees have beneficial effects on the environment. Approximately 41% of the annual benefits were attributed to environmental values. Energy savings were 68% of this value, a substantial sum of about $11 per tree. Benefits associated with storm-water runoff reduction represented 21% ($3.25/tree) of the total benefits, with carbon dioxide reductions ($1.71/tree) and air quality benefits ($0.70/tree) accounting for the remaining 11% of estimated total annual benefits. As in most cities, annual increases in property value were the largest benefit produced by trees in Cheyenne.

While species vary in their ability to produce benefits, common characteristics of trees within tree-type classes aid in identifying the most beneficial street trees in Cheyenne (Figure 5). As is typical in most cities, Cheyenne's larger trees – deciduous and conifer -- generally produced the most benefits. The anomaly was small-stature deciduous trees; for total benefits, these trees provided a higher average return for the investment dollar than medium deciduous trees. This was primarily due to increased property value benefits associated with leaf area and total tree numbers. Medium-size trees were few and predominantly young; over 300 of the 402 were less than 6” dbh. Over half were Quaking aspen with less leaf area than the many mature small trees. There were 1,543 small trees, 1,262 at <6” dbh and 281 >than 6” dbh.

Where environmental benefits are the primary concern, large deciduous trees provided the highest level of average benefits in Cheyenne. Large conifers in parks provided more environmental benefits than those on streets, with higher savings associated with heating, rainfall interception and CO_2. Small conifers produced the fewest benefits of all tree types, with park trees again providing more environmental benefits than street trees ($1.16 vs. $0.76/tree).

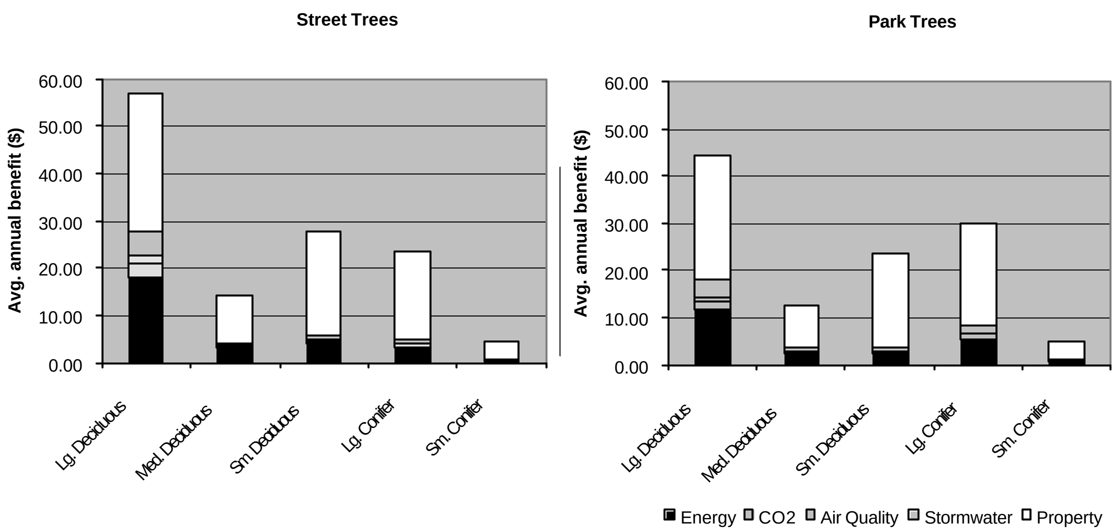


Figure 5. Average annual street and park benefits per tree by tree types.

Average annual benefits increased from $20/tree for small trees to $89/tree for large trees (Fig. 6). Property values and aesthetic benefits were most important for young trees because the result is influenced by growth rate, particularly the annual increase in leaf area. Conversely, storm-water runoff reduction benefits were greatest for older trees because leaf area and crown diameter influence rainfall interception. Energy benefits also increased, with larger crowns and leaf area providing more heating and cooling savings to residences.

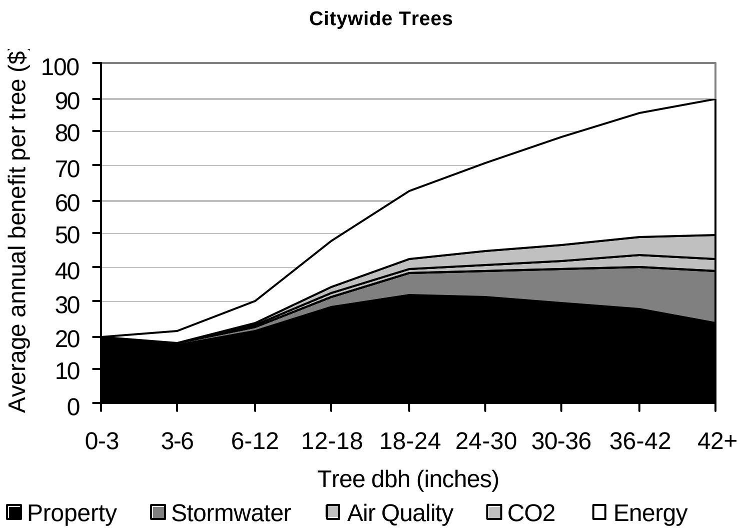


Figure 6. Average annual benefits per tree by dbh size classes.

Table 18 shows the distribution of total annual benefits in dollars for the predominant street and park species in Cheyenne. Cottonwood and Siberian elm, accounting for 33% of the tree population, produced nearly 48% of all benefits. Two additional species -- Blue spruce and Green ash -- provided another 18% of the benefits. Together, these four species represent 53% of the total population but produce 66% of the benefits (Fig. 7). Ponderosa pine (6%) and Honeylocust (5%) are also important produces of benefits.

Table 18. Total annual benefits ($) for predominant street and park trees in Cheyenne.

Species	Energy	CO2	Air Quality	Stormwater	Property	Total	% Total
Cottonwood	74,459	10,678	3,347	22,831	106,086	217,402	31.7
American elm	5,387	686	747	1,400	9,852	18,073	2.6
Silver maple	3,566	578	450	1,199	5,972	11,764	1.7
Hackberry	2,815	324	344	677	7,652	11,813	1.7
Siberian elm	28,270	5,171	3,982	9,194	61,938	108,555	15.8
Willow	4,940	635	73	1,474	8,764	15,885	2.3
Honeylocust	10,670	1,318	1,316	2,225	16,291	31,821	4.6
Boxelder maple	6,019	807	656	1,535	11,163	20,181	2.9
Green ash	15,867	2,392	1,940	4,474	29,727	54,400	7.9
Birch	595	92	62	95	779	1,622	0.2
Crabapple	2,257	293	251	343	8,092	11,235	1.6
Blue spruce	11,919	3,533	(2,171)	4,625	53,854	71,760	10.5
Ponderosa pine	9,282	1,027	156	2,317	31,982	44,763	6.5
Fir	151	38	(22)	53	1,037	1,256	0.2
Russian olive	375	51	47	91	2,625	3,190	0.5
Chokecherry	422	53	49	139	6,286	6,949	1.0
Quaking aspen	326	50	24	70	2,597	3,066	0.4
Pinyon pine	152	16	6	31	762	966	0.1
Pine	364	44	(9)	110	4,110	4,619	0.7
Juniper species	337	37	10	73	1,748	2,205	0.3
Other Street Trees	5,542	811	380	1,406	19,435	45,341	6.6
Other Park Trees	3,271	491	229	939	11,971	24,414	3.6
Street Tree Total	126,116	19,175	11,730	36,238	224,372	417,632	60.87
Park Tree Total	60,870	9,960	179	19,063	178,351	268,423	39.13
Total	186,986	29,135	11,909	55,301	402,723	686,055	100.00

The 6300 small, young trees (<6” dbh) in Cheyenne accounted for 37% of the municipal tree population and 17% of the annual benefits ($19/tree). Eventually large-growing species – Ponderosa, Cottonwood, Siberian elm, Green ash – composed 32% of this younger population with the smaller-stature crabapple adding another 6%.

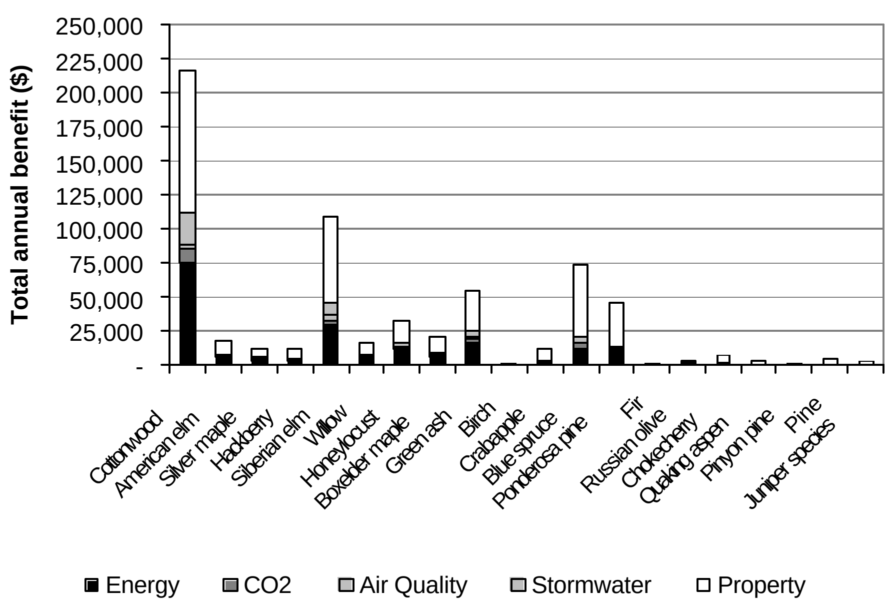


Figure 7. Cottonwood account for 20% of all trees and produce nearly one-third of all benefits. Because of rapid growth and large size they contribute substantially to property value and energy benefits.

Maturing trees (6-18" dbh) were 37% of the population and contributed 35 % of the annual benefits ($38/tree). Blue spruce, Ponderosa, Cottonwood, Siberian elm and Green ash were the predominant species in these size classes (71%). Over three-quarters of the trees in the mature tree size classes (18-30" dbh) were Cottonwood, Siberian elm and Blue spruce. Mature trees composed 20% of the entire population and added 34% of the annual benefits to the community ($66/tree). About 7% of the population consisted of large, old trees, those greater than 30" dbh, producing over 13% of the total benefits ($80/tree). Nearly all were Cottonwood (84%) with Siberian elm a distant second (9%).

CHAPTER FIVE—MANAGEMENT IMPLICATIONS

Street trees are only one component of a functional urban forest. In some cities, they are the most important component, defining the values of the community, thereby providing a portal to different neighborhoods and shopping districts. In other cities, street trees are treated with less concern than are parks, greenbelts, and private plantings. In any case, cities must seek to maintain a functional municipal forest that is both healthy and safe. In Cheyenne, a prairie city once overwhelmed by wind and accompanying dust storms (Fig. 8), there is no doubt that trees are valued as an integral component of the city (Fig. 9).

Figure 8. A treeless Cheyenne is shown above during the Dustbowl. An increasing number of trees were planted to buffer the city from the effects of weather and drought (Photo courtesy of the Cheyenne Botanic Gardens Website 2004).

Cheyenne's urban forest reflects the values, lifestyles, preferences, and aspirations of current and past residents. It is a dynamic legacy, on one hand dominated by trees planted over 50 years ago and, at the same time, constantly changing as new trees are planted and others mature. Although this study provides a "snapshot" in time of the resource, it also serves as an opportunity to speculate about the future. Given the status of Cheyenne's municipal tree population, what future trends are likely and what management challenges will need to be met to achieve urban forest sustainability?

Figure 9. The result of the city and citizens' planting efforts can be seen along every major street and throughout the community parks.

Achieving resource sustainability will produce long-term net benefits to the community while reducing the associated costs incurred with managing the resource. The structural features of a sustainable urban forest include adequate complexity (species and age diversity), well-adapted healthy trees, appropriate tree numbers and management. Focusing on these components – resource complexity, resource extent, pruning and maintenance – refines broader municipal tree management goals.

RESOURCE COMPLEXITY

Although 58 different species have been planted along streets and in parks, Cottonwood is the dominant tree, accounting for 20% of all municipal trees and about 32% of the benefits. Species diversity was adequate when viewed on a citywide scale, but planting for population stability requires more than simply planting "other trees" when a single species is planted beyond a set threshold (e.g., 10% of total population). Figure 10 displays new and replacement planting trends. These eight species composed 55% of the new plantings in the 1992 inventory. Five of the eight have proven to be well adapted and have the longevity to produce benefits the community depends upon.

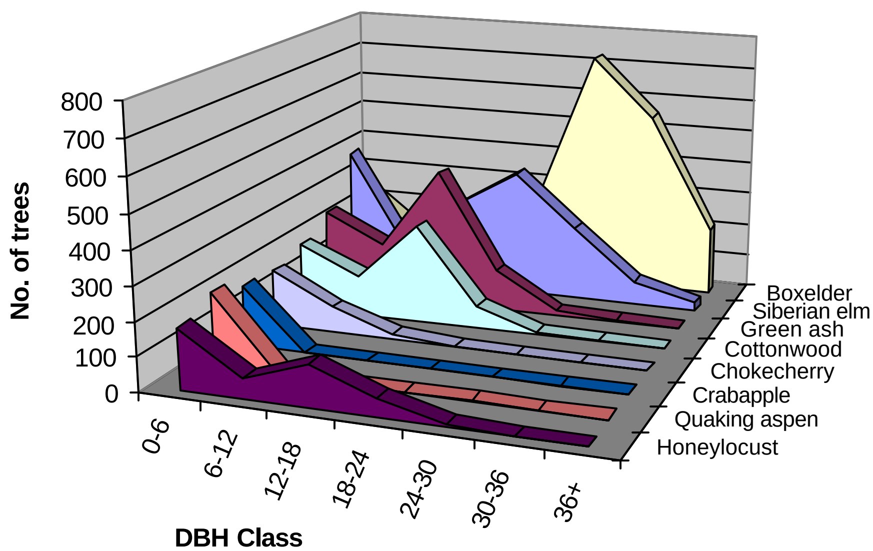


Figure 10. Top street trees planted by numbers and DBH in 1992.

Chokecherry, Crabapple and Quaking aspen were relative newcomers and unproven at the time of the inventory. Twelve years later, Chokecherry and Crabapple continue to perform well, although small in size. Quaking aspen, although larger than Crabapple and Chokecherry, produces fewer benefits, requires more irrigation and has a significantly higher mortality rate. It is not well suited to performing cost-effectively as a street tree. It is important to note that these four species are smaller in stature than Cottonwood and Elms and, therefore, will not produce the same level of benefits as they mature.

As evident in Figure 11, large, long-lived deciduous trees were those that reach functional age. Substantial tree numbers in large DBH classes indicate proven adaptability amongst these trees. Some of these species are no longer planted in large numbers. In the past 10 years (as compared to historic plantings), the number of Cottonwood and Siberian elms being planted along streets have decreased due to concerns over restricted planting space as well as the hazard and liability issues associated with large weak-wooded species. New plantings of these species are currently being promoted only in parks and along those street rights-of-way allowing adequate space. Since 1992, the UFD has encouraged residents to plant additional American elm, Hackberry, Red and Bur oak,

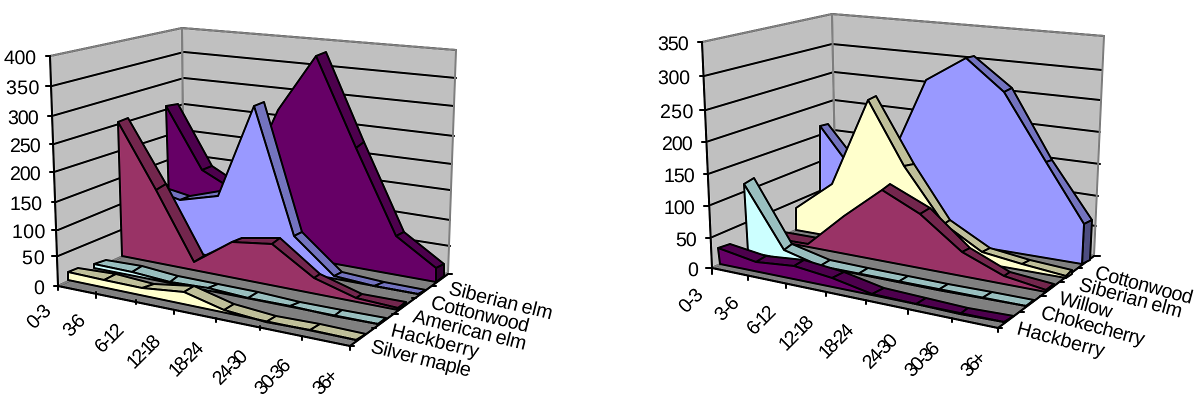


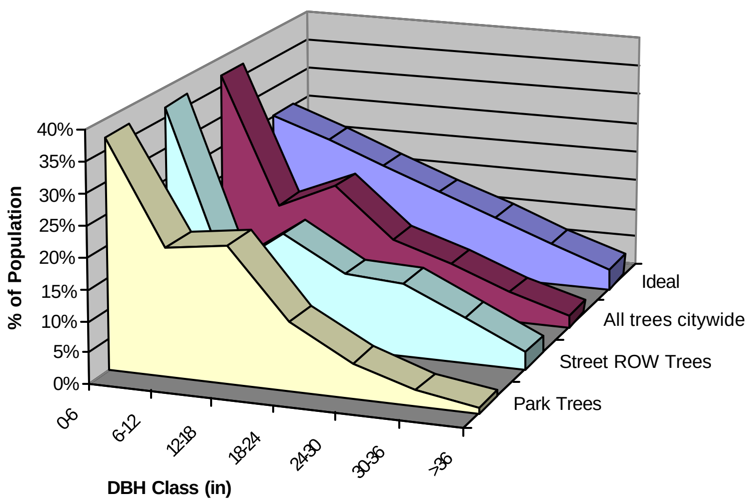
Figure 11. Age distribution of street (left) and park (right) trees in Cheyenne that are currently producing the largest average annual benefits on a per tree basis.

and Littleleaf linden along streets in an effort to further diversify the large-stature broadleaf street and park tree population. Planting these larger trees where space allows will be key to maintaining the flow of benefits the community currently enjoys as the senescent portions of the Cottonwood and Siberian elm populations require removal. The shift towards planting small-stature species or trees that have not proven to be long-lived could have the potential to reduce the future level of benefits afforded the community, but the placement for these smaller trees tends to be appropriate – under utility lines and in other restricted locations. Further evaluation of species performance and placement over the long-term is recommended with additional emphasis on planting long-lived large stature trees.

Condition class is likely to be an overriding indicator of selecting well-adapted and appropriate trees. Appendix C displays relative performance index (RPI) values based on the proportion of each public tree classified as “good” divided by the proportion of the total population that that tree represented. Indications are that newer, long-lived tree selections like Red oak (3.49), Littleleaf linden (2.07), and Crabapple are performing well (1.35). Hackberry, established longer, also maintains higher than average ‘good’ condition ratings (1.09).

While RPI values can be used to indicate trees well suited to Cheyenne conditions, it is important to remember that some species with low values may represent populations with an even-age distribution that are senescing. An example is Cottonwood. Though most of these trees’ functional lives are past, they have served the city well throughout their long lives and to not replant these species in parks would be shortsighted. Conversely, the predominance of species like Cottonwood and Siberian elm leaves Cheyenne open to potentially catastrophic losses from disease and insect infestation. Currently, Siberian elm trees have been lost by the thousands elsewhere in the U.S. due to infestation by the banded elm bark beetle, an insect now present in Wyoming elms. The Cottonwood and Siberian elm populations account for 33% of the tree population and nearly half of all benefits produced by trees. Therefore, it is vital that the city continues efforts to diversify by limiting the numbers of Cottonwood and Siberian elm planted to ideal planting levels and increasing the numbers of other large-growing species like Linden, Hackberry, and Oak. This appears to be the trend the UFD is following for park plantings; however, the city has limited control over what homeowners plant in the street rights-of-way. The fact that homeowners planted more quaking aspen than any of the other 10 predominant street tree species (Fig. 2) in the 1990s demonstrates the continuing need to educate the public to the importance of selecting long-lived, high benefit-producing species and perhaps the need to establish a planting ordinance specifying approved species to plant by location types.

The citywide age distribution of all trees was inline with the "ideal" distribution as described above, though the numbers of young trees were elevated and the number of functional trees were slightly less than ideal



( ). This distribution suggests that the strong program the UFD has in place for young tree care as well as the targeted maintenance for functionally maturing park trees is right on target. These priorities will insure that young trees will transition through their lifecycle in good health, minimizing the resources needed to maintain them, while functionally mature trees will perform at their peak to compensate for their lack in number. Park trees are providing the significant benefits they are to the community because they are well managed. The concern and challenge for Cheyenne rests with the street trees – where an equally strong maintenance program is needed but does not currently exist.

RESOURCE EXTENT

Canopy cover, or more precisely the amount and distribution of leaf surface area, is the driving force behind the urban forest's ability to produce benefits for the community. As canopy cover increases, so do the benefits afforded by leaf area. It is important to remember that street trees throughout the US—and those of Cheyenne—likely represent less than 10% of the entire urban forest (Moll and Kollin 1993). In other words, the benefits Cheyenne residents realize from all urban vegetation is far greater than the values found through this analysis. But due to their location and conflicts, street trees are typically the most expensive component to manage. The City of Cheyenne invests only $11,000 per year for street tree inspection and irrigation ($1.23/tree; $0.21/capita). It is unknown what amount residents expend on tree maintenance, but maximizing the return on the total investment is contingent upon maximizing and maintaining the canopy cover of these trees.

Increasing the street tree canopy cover requires a multifaceted approach in Cheyenne. Plantable spaces must be filled and use of large stature trees must be encouraged wherever feasible. In 1992 there were nearly 6,300 available street tree planting spaces in the city. The current estimate is that there are 5,600 empty planting basins available (Olson and Overstreet 2003). To encourage increasing the flow of tree-provided benefits over time, sites for large street trees should be planted first wherever possible, followed by those for medium and then small trees. As large, brittle trees like Siberian elm and Cottonwood are phased out, they should be replaced with the myriad of large-stature trees the UFD has experimented with and found suitable. These include varieties of Oak, Maple, Linden and Hackberry.

PRUNING & MAINTENANCE

Unfortunately, budget constraints of municipal tree programs often dictate the length of pruning cycles and maintenance regimes rather than the needs of the urban forest and its constituent components. In fact, pruning is programmed only for park trees in Cheyenne, not for street trees – that portion of the population capable of providing the most benefits to the community. Programmed pruning, under a reasonable timeline, can improve public safety by eliminating conflicts and increase benefits by improving tree health and condition. The non-existence of programmed street tree pruning is reflected in the generally poorer condition of Cheyenne's street trees when compared to regularly maintained park trees. There are three times as many street trees in poor condition compared to park trees. Over 42% of park trees are in good or better condition compared to less than 10% of the street trees. Any dollar savings realized by the city deferring street tree planting and maintenance to residents is done at a loss in tree value and the cumulative value of the street tree population (Miller and Sylvester 1981). Street trees in Cheyenne produce 42% more benefits than park trees. In nearby Fort Collins, CO, 75% of the street trees are in good to excellent condition, providing 72% more benefits than park trees. This suggests that when trees are maintained at a better condition level, they provide more benefits to the community.

Managed, programmed pruning is recommended on a 3-6 yr cycle in residential areas; annual maintenance is suggested for commercial districts (Miller 1997). In their study of Milwaukee, WI, Miller and Sylvester (1981) found that extending pruning cycles beyond 4 or 5 years resulted in a loss of tree value that exceeded any savings accrued by deferring maintenance. In order to maintain consistency and maximize urban forest benefits while reducing city liabilities and public safety conflicts, the city of Modesto, CA had also found 4 years to be the ideal pruning cycle for their municipal forest (Gilstrap 1983). Furthermore, Anderson and Eaton (1986) suggested that an adequate and systematic pruning and inspection program was the first step to avoiding liability stemming from trees. Nearly one-third (2,930) of all Cheyenne street trees needed general pruning compared to less than 10% of the park trees in 1992. Since 1992, the UFD has used a "species pruning" approach for park trees to target specific species to reduce the total number of trees needing pruning over the short-term. Street trees would benefit from a similar programmed approach. For example, in residential areas, focusing on the pruning of mature and senescent Cottonwood and Siberian elm would rectify over 50% of the trees along streets categorized as needing general pruning.

CHAPTER SIX—CONCLUSION

The approach used in this analysis not only provided sufficient data to describe structural characteristics of the street tree population, but, by using tree growth data modeled for the city, assessed the environmental benefits trees provide the city and its residents. In addition, the BCR was calculated and management needs were identified. This approach was based on established statistical methods and was intended to provide a general accounting of the benefits produced by street trees in Cheyenne that can be utilized to make informed management and planning decisions.

Cheyenne's trees are a valuable asset, providing approximately $686,000 in annual benefits. These benefits to the community were most pronounced in increased local property values, but environmental benefits were also significant with energy savings notably high. Thus, street and park trees were found to provide a particularly important function in maintaining air quality, reducing the amount of particulate matter by filtering the air, and reducing heating consumption by acting as windbreaks.

Cheyenne's street trees are a fantastically dynamic resource. Managers of this resource and the community alike can delight in knowing that street trees do improve the quality of life in Cheyenne, but they are also faced with a fragile resource that needs constant care to maximize and sustain these benefits through the foreseeable future. In a city where the climate poses a constant challenge to tree growth and health, this is no easy task. The challenge will be to maximize net benefits from available growth space over the long-term, providing an urban forest resource that is both functional and sustainable. The effects of the current extended drought are potentially devastating to the Cheyenne tree population. Extensive public education on appropriate pruning and irrigation frequencies that demonstrate the resultant beneficial effects on tree health is necessary and could improve the functionality, longevity, and the overall benefits produced by street trees. Continued replacement of senescent Cottonwood and Siberian elm with a variety of medium and large-stature broadleaf deciduous tree species is recommended. A thorough inventory of street trees is currently being conducted which will allow the city to further evaluate the change and growth of the street tree population since the 1992 inventory. In addition, all park trees are currently undergoing evaluation.

This analysis has provided the information necessary for resource managers to weigh the citywide needs with the more specific needs of park and residential areas. Utilizing the structural indices outlined above—diversity index, relative performance values, importance values, condition values, and age distribution tables, conflicts, etc.—along with benefit data, provide the requisite understanding for short- and long-term resource management.

Recommendations to management include the following:

- Achieving resource sustainability requires increasing diversity by balancing new plantings of proven, long-lived species with newer successful introductions, maximizing available growth space to provide the largest amount of leaf area and canopy coverage as the trees mature. Continued replacement of senescent Cottonwood and Siberian elm with a variety of long-lived medium and large-stature broadleaf deciduous tree species is recommended.

- Focusing planting efforts along streets where stocking levels are lowest will improve the distribution of benefits provided to all neighborhoods. To this end a current inventory of all Cheyenne street trees will aid in overseeing and tracking management.

- Tree health and pruning management needs for street trees were substantial compared to well-maintained park trees. Extensive public education on appropriate pruning and irrigation frequencies to demonstrate the resultant beneficial effects on tree health is necessary; this could assist in improving the functionality, longevity, and the overall benefits produced by street trees. Functionality and longevity would be further bolstered by the establishment of a consistent pruning program for street trees.

CHAPTER SEVEN—REFERENCES

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APPENDIX A: TREE DISTRIBUTION

Table A-1. Tree numbers by size class (diameter at breast height [dbh] in inches) for all street and park trees. Tree types are BDL, BDM, and BDS for broadleaf deciduous large, medium, and small, CEL, CES for coniferous evergreen large, medium, and small.

Tree Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	42+	Total	% Total
Cottonwood/poplar	280	195	197	308	533	983	702	222	48	3,468	20.4
Siberian elm	295	228	343	409	432	241	81	21	6	2,056	12.1
Green ash	348	181	223	463	130	12	1	-	-	1,358	8.0
Honeylocust	76	192	143	302	67	7	-	-	-	787	4.6
Boxelder maple	127	49	56	122	54	6	1	-	-	415	2.4
American elm	28	8	18	65	76	26	3	2	-	226	1.3
Silver maple	16	17	25	56	36	23	7	2	-	182	1.1
Willow	5	7	63	117	88	37	11	3	-	331	1.9
Hackberry	34	23	33	77	30	-	-	-	-	197	1.2
Quaking aspen	137	86	10	-	-	-	-	-	-	233	1.4
Russian olive	115	17	7	10	3	-	-	-	-	152	0.9
Birch	13	15	41	21	3	-	-	-	-	93	0.5
Crabapple	230	167	129	18	1	-	-	-	-	545	3.2
Common chokecherry	254	59	2	1	-	-	-	-	-	316	1.9
Blue spruce	377	215	529	611	317	118	13	-	-	2,180	12.8
Ponderosa/Austrian pine	334	199	446	575	138	17	1	-	-	1,710	10.1
Pine	229	37	13	15	5	1	-	-	-	300	1.8
Fir	68	5	2	9	3	-	-	-	-	87	0.5
Juniper species	174	119	126	20	-	-	-	-	-	439	2.6
Pinyon pine	64	123	41	3	-	-	-	-	-	231	1.4
BDL OTHER	316	144	87	116	42	30	19	6	2	762	4.5
BDM OTHER	50	7	7	10	2	-	-	-	-	76	0.4
BDS OTHER	277	143	79	23	7	1	-	-	-	530	3.1
CEL OTHER	125	33	47	32	15	2	-	-	-	254	1.5
CES OTHER	36	23	20	3	-	-	-	-	-	82	0.5
Street Tree Total	1,939	1,340	997	1,604	1,089	1,055	645	201	37	8,907	52.4
Park Tree Total	2,069	952	1,690	1,782	893	449	194	55	19	8,103	47.6
Grand Total	4,008	2,292	2,687	3,386	1,982	1,504	839	256	56	17,010	100.0

APPENDIX B: METHODOLOGY AND PROCEDURES

This analysis combines results of a citywide inventory with benefit-cost modeling data to produce four types of information (Maco 2003):

1. Resource structure (species composition, diversity, age distribution, condition, etc.)
2. Resource function (magnitude of environmental and aesthetic benefits)
3. Resource value (dollar value of benefits realized)
4. Resource management needs (sustainability, pruning, planting, and conflict mitigation)

This section describes the inputs and calculations used to derive the aforementioned outputs: growth modeling, identifying and calculating benefits, estimating magnitude of benefits provided, assessing resource unit values, calculating net benefits and benefit-cost ratio, and assessing structure.

GROWTH MODELING

Cheyenne's tree database contained information on 17,010 street and park trees, including species and size. There were a total of 58 broadleaf and conifer species.
A combination of regional tree growth models from Fort Collins, CO and local models developed from Cheyenne data were used as the basis for modeling Cheyenne tree growth. Applying Fort Collins's models to cities within the same climate region assumes

that Fort Collins's trees grow at the same rate and to the same dimensions throughout the region. Using the Cheyenne Urban Forestry Division's 1992 municipal tree database, a stratified random sample of six street and park tree species were measured to establish relations between tree age, size, leaf area and biomass for comparison with the regional growth curves. This comparison formed the basis for adjusting the regional curves to model Cheyenne tree growth and estimate the magnitude of annual benefits derived from the Cheyenne street and park tree resources. The six Cheyenne species measured were Silver maple (*Acer saccharinum*), Green ash (*Fraxinus pennsylvanica*), Honeylocust (*Gleditsia triacanthos*), Littleleaf linden (*Tilia cordata*), Blue spruce (*Picea pungens*), and Siberian elm (*Ulmus pumila*). Because the Blue spruce models could be used to model growth of other conifers in the city, only the five broadleaf deciduous tree species were used to compare and adjust the Fort Collins' broadleaf deciduous tree models for use in Cheyenne.

For both the regional and local growth models information spanning the life cycle of predominant tree species was collected. City inventories were stratified into 9 diameter-at-breast height (DBH) classes: 0-7.62 in (0-7.62 cm), 3-6 in (7.62-15.24 cm), 6-12 in (15.24-30.48 cm), 12-18 in (30.48-45.72 cm), 18-24 in (45.72-60.96 cm), 24-30 in (60.96-76.2 cm), 30-36 in (76.2-91.44), 36-42 in (91.44-106.68 cm), and >42 in (106.68 cm). Thirty-five to 70 randomly selected trees of each species were selected to survey, along with an equal number of alternative trees. Tree measurements included DBH (to nearest 0.1 cm by tape), tree crown and bole height (to nearest 0.5m by altimeter), crown diameter in two directions (parallel and perpendicular to nearest street to nearest 0.5m by tape), tree condition and location, and crown pruning level (percentage of crown removed by pruning). Replacement trees were sampled when trees from the original sample population could not be located. Tree age was determined from interviews with residents, the Director and Assistant Director of the Urban Forestry Division, and historical planting records. Fieldwork was conducted in August and September 2002.

Crown volume and leaf area were estimated from computer processing of tree crown images obtained using a digital camera. The method has shown greater accuracy than other techniques (±20 percent of actual leaf area) in estimating crown volume and leaf area of open-grown trees (Peper and McPherson 2003).

Linear regression was used to fit predictive models—DBH as a function of age—for each of the 22 sampled species in Fort Collins. Predictions of leaf surface area (LSA), crown diameter, and height metrics were modeled as a function of DBH using best-fit models (Peper et al. 2001). The same methods were applied to develop the models for the six species that Cheyenne and Fort Collins shared in common. Midpoint DBH size class predictions for each growth parameter were calculated for each city's trees. The proportional difference in tree size by dbh class was calculated and averaged across the species to develop factors to adjust the Fort Collins' tree models to represent Cheyenne tree size. Table B-1 shows that across species and age classes, Cheyenne's deciduous broadleaf trees are about 18% shorter than Fort Collins' trees, not surprising, considering the pruning effect of freezing, high winds in winter and higher elevation. There is a similarly proportional difference for every other tree dimension except crown diameter, which on average, is about 9% smaller than Fort Collins' average crown diameter.

Table B-1. Cheyenne tree dimensions as a proportion of Fort Collins' tree dimensions for each DBH class midpoint. For example, 15" DBH trees in Cheyenne average 80.3% of height of a Fort Collins' tree.

DBH Class	Midpoint DBH (in)	% of Height	% of Crown Height	% of Crown Diameter	% of Crown Projection	% of Leaf Area
1	1.5	97.0	88.7	87.9	78.1	89.4
2	4.5	81.4	74.6	87.9	78.1	89.4
3	9	79.6	75.6	85.5	74.0	85.9
4	15	80.3	78.4	88.7	79.1	80.9
5	21	81.5	80.9	92.5	85.7	81.4
6	27	80.5	80.6	92.9	86.8	79.4
7	33	79.6	80.4	93.4	88.1	79.0
8	39	78.9	80.3	93.9	89.8	80.8
9	45	78.4	80.3	94.5	91.6	85.1
mean	21.7	81.9	80.0	90.8	83.5	83.5
std error	5.1	1.9	1.3	1.1	2.1	1.4

IDENTIFYING & CALCULATING BENEFITS

Annual benefits for Cheyenne's street trees were estimated for the year 2001. Growth rate modeling information was used to perform computer-simulated growth of the existing tree population for one year and account for the associated annual benefits. This "snapshot" analysis assumed that no trees were added to, or removed from, the existing population during the year. The approach directly connects benefits with tree size variables such DBH and LSA. Many functional benefits of trees are related to leaf-atmosphere processes (e.g., interception, transpiration, photosynthesis), and, therefore, benefits increase as tree canopy cover and leaf surface area increase.

Prices were assigned to each benefit (e.g., heating/cooling energy savings, air pollution absorption, storm-water runoff reduction) through direct estimation and implied valuation as environmental externalities. Implied valuation is used to price society's willingness to pay for the environmental benefits trees provide. Estimates of benefits are initial approximations—as some benefits are difficult to quantify (e.g., impacts on psychological health, crime, and violence). In addition, limited knowledge about the physical processes at work and their interactions makes estimates imprecise (e.g., fate of air pollutants trapped by trees and then washed to the ground by rainfall). Therefore, this method of quantification was not intended to account for each penny. Rather, this approach was meant to be a general accounting of the benefits produced by urban trees; an accounting with an accepted degree of uncertainty that can, nonetheless, provide a platform on which decisions can be made (Maco 2003).

Energy Savings

Buildings and paving, along with low canopy and soil cover, increase the ambient temperatures within a city. Research shows that even in temperate climate zones—such as those of the Pacific Northwest—temperatures in urban centers are steadily increasing by approximately 0.5°F (0.3°C) per decade. Winter benefits of this warming do not compensate for the detrimental effects of magnifying summertime temperatures. Because electric demand of cities increases about 1-2% per 1°F (3-4% per °C) increase in temperature, approximately 3-8% of current electric demand for cooling is used to compensate for this urban heat island effect of the last four decades (Akbari et al. 1992).

Warmer temperatures in cities, compared to surrounding rural areas, have other implications. Increases in CO_2 emissions from fossil fuel power plants, municipal water demand, unhealthy ozone levels, and human discomfort and disease are all symptoms associated with urban heat islands. In Cheyenne, there are many opportunities to ameliorate the problems associated with hardscape through strategic tree planting and stewardship of existing trees allowing for streetscapes that reduce storm-water runoff, conserve energy and water, sequester CO_2, attract wildlife, and provide other aesthetic, social, and economic benefits through urban renewal developments and new development.

For individual buildings, street trees can increase energy efficiency in the summer and increase or decrease energy efficiency in winter, depending on placement. Solar angles are important when the summer sun is low in the east and west for several hours each day. Tree shade to protect east—and especially west—walls help keep buildings cool. In the winter, solar access on the southern side of buildings can warm interior spaces.

Trees reduce air infiltration and conductive heat loss from buildings. Rates at which outside air infiltrates into a building can increase substantially with wind speed. In cold, windy weather, the entire volume of air in a poorly sealed home may change two to three times per hour. Even in newer or tightly sealed homes, the entire volume of air may change every two to three hours. Trees can reduce wind speed and resulting air infiltration by up to 50%, translating into potential annual heating savings of 25% (Heisler 1986). Reductions in wind speed reduce heat transfer through conductive materials as well. Cool winter winds, blowing against single-pane windows, can contribute significantly to the heating load of homes and buildings by increasing the temperature gradient between inside and outside temperatures.

Electricity and Natural Gas Methodology

Calculating annual building energy use per residential unit (Unit Energy Consumption [UEC]) is based on computer simulations that incorporate building, climate and shading effects, following methods outlined by McPherson and Simpson (1999). Changes in UECs from trees (ΔUECs) were calculated on a per tree basis by comparing results before and after adding trees. Building characteristics (e.g., cooling and heating equipment saturations, floor area, number of stories, insulation, window area, etc.) are differentiated by a building's vintage, or age of construction: pre-1950, 1950-1980 and post-1980. Typical meteorological year (TMY2) weather data for Cheyenne Airport were used (Marion and Urban 1995). Shading effects for each tree species measured were simulated at three tree-building distances, eight orientations and nine tree sizes.

Shading coefficients for tree crowns in leaf were based on a photographic method that estimates visual density. These techniques have been shown to give good estimates of light attenuation for trees in leaf (Wilkinson 1991). Visual density was calculated as the ratio of crown area computed with and without included gaps. Crown areas were obtained from digital images isolated from background features using the method of Peper and McPherson (2003). Values for trees not measured, and for all trees not in leaf, were based on published values where available (McPherson 1984, Hammond et al. 1980). Values for remaining species were assigned based on taxonomic considerations (trees of the same genus assigned the same value) or observed similarity in the field to known species. Foliation periods for deciduous trees were obtained from the literature (McPherson 1984, Hammond et al. 1980) and adjusted for Cheyenne's climate based on consultation with the assistant city forester (Randy Overstreet, Assistant Urban Forester, City of Cheyenne, pers comm. 3/3/2003).

Tree distribution by location (e.g. frequency of occurrence at each location determined from distance between trees and buildings (setbacks), and tree orientation with respect to buildings) specific to Cheyenne was used to calculate average energy savings per tree as a function of distance and direction. Setbacks were assigned to four distance classes: 0-20 ft, 20-40 ft, 40-60 ft and >60 ft. It was assumed that street trees within 60 ft of buildings provided direct shade on walls and windows. Savings per tree at each location were multiplied by tree distribution to determine location-weighted savings per tree for each species and DBH class that was independent of location. Location-weighted savings per tree were multiplied by number of trees in each species/DBH class and then summed to find total savings for the city. Tree location measurements were based on samples of 275 right-of-way trees and 79 park trees taken in the summer of 2003.

Land use (single family residential, multifamily residential, commercial/industrial, other) for right-of-way trees was based on the same tree sample. Park trees were distributed according to the predominant land use surrounding each park. The same tree distribution was used for all land uses.

Three prototype buildings were used in the simulations to represent pre-1950, 1950 and post-1980 construction practices for Cheyenne (West Mountain census region, Denver) (Ritschard et al. 1992). Building footprints were modeled as square, which was found to be reflective of average impacts for large building populations (Simpson 2002). Buildings were simulated with 1.5-ft overhangs. Blinds had a visual density of 37%, and were assumed closed when the air conditioner is operating. Summer and winter thermostat settings were 78° F and 68° F during the day, respectively, and 60° F at night. Unit energy consumptions were adjusted to account for saturation of central air conditioners, room air conditioners, and evaporative coolers (Table B-2).

Table B-2. Saturation adjustments for cooling.

	Single family detached			Mobile Homes			Single family attached			MF 2-4 units			MF 5+ units			Commercial/ Industrial		Institutional/ Transportation
	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	Small	Large	
Cooling equipment factors																		
Central air/heat pump	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%
Evaporative cooler	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	0%
Wall/window unit	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	0%
None	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cooling saturations																		
Central air/heat pump	47%	55%	78%	47%	55%	78%	47%	55%	78%	47%	55%	78%	47%	55%	78%	63%	63%	0%
Evaporative cooler	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	2%	0%
Wall/window unit	23%	25%	11%	23%	25%	11%	23%	25%	11%	23%	25%	11%	23%	25%	11%	13%	13%	0%
None	60%	39%	22%	60%	39%	22%	60%	39%	22%	60%	39%	22%	60%	39%	22%	22%	22%	0%
Adjusted cooling saturation	53%	62%	81%	53%	62%	81%	53%	62%	81%	53%	62%	81%	53%	62%	81%	67%	67%	0%

Single-Family Residential Adjustments

Unit energy consumptions for simulated single-family residential buildings were adjusted for type and saturation of heating and cooling equipment, and for various factors that modified the effects of shade and climate modifications on heating and cooling loads, using the expression,

$$?UEC_x = ?UEC^{sh}_{SFD} \times F_{sh} + ?UEC^{cl}_{SFD} \times F_{cl}$$

where $F_{sh} = F_{equipment} \times APSF \times F_{adjacent\ shade} \times F_{multiple\ tree}$ Equation 1

$F_{cl} = F_{equipment} \times PCF$

and $F_{equipment} = Sat_{CAC} + Sat_{window} \times 0.25 + Sat_{evap} \times$ (0.33 for cooling and 1.0 for heating).

Total change in energy use for a particular land use was found by multiplying change in UEC per tree by the number of trees (N):

$$\text{Total change} = N \times ?UEC_x. \quad \text{Equation 2}$$

Subscript *x* refers to residential structures with 1, 2-4 or 5 or more units, *SFD* to single family detached structures which were simulated, *sh* to shade, and *cl* to climate effects.

Estimated shade savings for all residential structures were adjusted by factors that accounted for shading of neighboring buildings, and reductions in shading from overlapping trees. Homes adjacent to those with shade trees may benefit from their shade. For example, 23% of the trees planted for the Sacramento Shade program shaded neighboring homes, resulting in an estimated energy savings equal to 15% of that found for program participants; this value was used here ($F_{adjacent\ shade} = 1.15$). In addition, shade from multiple trees may overlap, resulting in less building shade from an added tree than would result if there were no existing trees. Simpson (2002) estimated that the fractional reduction in average cooling and heating energy use per tree were approximately 6% and 5% percent per tree, respectively, for each tree added after the first. Simpson (1998) also found an average of 2.5 to 3.4 existing trees per residence in Sacramento. A multiple tree reduction factor of 85% was used here, equivalent to approximately three existing trees per residence.

In addition to localized shade effects, which were assumed to accrue only to street trees within 18-60 ft (5-18 m) of buildings; lowered air temperatures and wind speeds from neighborhood tree cover (referred to as climate effects) produce a net decrease in demand for summer cooling and winter heating. Reduced wind speeds by themselves may increase or decrease cooling demand, depending on the circumstances. To estimate climate effects on energy use, air temperature and wind speed reductions as a function of neighborhood canopy cover were estimated from published values following McPherson and Simpson (1999), then used as input for building energy use simulations described earlier. Peak summer air temperatures were assumed reduced by 0.4 °F for each percentage increase in canopy cover. Wind speed reductions were based on the canopy cover resulting from the addition of the particular tree being simulated to that of the building plus other trees. A lot size of 10,000 ft^2 (929 m^2) was assumed.

Dollar value of electrical and natural gas (Cheyenne Light, Fuel, and Power Company 2003) energy savings were based on electricity and natural gas prices of $0.084 per kWh and $0.80 per therm, respectively. Cooling and heating effects were reduced based on the type and saturation of air conditioning (Table B-2) or heating (Table B-3) equipment by vintage. Equipment factors of 33% and 25% were assigned to homes with evaporative coolers and room air conditioners, respectively. These factors were combined with equipment saturations to account for reduced energy use and savings compared to those simulated for homes with central air conditioning ($F_{equipment}$). Building vintage distribution was combined with adjusted saturations to compute combined vintage/saturation factors for air conditioning (Table B-2). Heating loads were converted to fuel use based on efficiencies in Table B-3. The "other" and "fuel oil" heating equipment types were assumed natural gas for the purpose of this analysis. Building vintage distributions were combined with adjusted saturations to compute combined vintage/saturation factors for natural gas and electric heating (Table B-4).

Table B-3. Saturation adjustments for heating

Electric heating																	
	Single family detached			Mobile Homes			Single family attached			MF 2-4 units			MF 5+ units			Commercial/ Industrial		Institutional/ Transportation
Equipment efficiencies	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	Small	Large	
AFUE	0.75	0.78	0.78	0.75	0.78	0.78	0.75	0.78	0.78	0.75	0.78	0.78	0.75	0.78	0.78	0.78	0.78	0.78
HSPF	6.8	6.8	8	6.8	6.8	8	6.8	6.8	8	6.8	6.8	8	6.8	6.8	8	8	8	8
HSPF	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412	3.412
Electric heat saturations																		
Electric resistance	3.0%	6.0%	19.0%	3.0%	6.0%	19.0%	3.0%	6.0%	19.0%	3.0%	6.0%	19.0%	3.0%	6.0%	19.0%	19.0%	19.0%	19.0%
Heat pump	0.5%	1.0%	3.2%	0.5%	1.0%	3.2%	0.5%	1.0%	3.2%	0.5%	1.0%	3.2%	0.5%	1.0%	3.2%	3.2%	3.2%	3.2%
Adjusted saturations	0.7%	1.5%	4.7%	0.7%	1.5%	4.7%	0.7%	1.5%	4.7%	0.7%	1.5%	4.7%	0.7%	1.5%	4.7%	4.7%	4.7%	4.7%
Natural Gas and other heating																		
Natural gas	47%	50%	44%	47%	50%	44%	47%	50%	44%	47%	50%	44%	47%	50%	44%	44%	44%	44%
Oil	20%	25%	11%	20%	25%	11%	20%	25%	11%	20%	25%	11%	20%	25%	11%	11%	11%	11%
Other	30%	18%	22%	30%	18%	22%	30%	18%	22%	30%	18%	22%	30%	18%	22%	22%	22%	22%
NG saturations	97%	93%	78%	97%	93%	78%	97%	93%	78%	97%	93%	78%	97%	93%	78%	78%	78%	78%

Table B-4. Building vintage distribution and combined vintage/saturation factors for heating and air conditioning.

	Siingle family detached			Mobile Homes			Single family attached			MF 2-4 units			MF 5+ units			Commercial/Industrial		Institutional/
	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	pre-1950	1950-1980	post-1980	Small	Large	Transportation
Vintage distribution by building type	36.0%	33%	31%	36%	33%	31%	36%	33%	31%	36%	33%	31%	36%	33%	31%	100%	100%	100%
Tree distribution by vintage and building type	22.8%	21.3%	19.7%	1.5%	01.4%	1.3%	2.2%	2.1%	1.9%	0.4%	0.4%	0.4%	1.4%	1.3%	1.2%	8.3%	8.0%	4.4%
Combined vintage, equipment saturation factors for cooling																		
Cooling factor: shade	11.72%	12.83%	15.54%	2.09%	0.83%	1.00%	1.00%	1.09%	1.32%	0.16%	0.17%	0.21%	0.29%	0.32%	0.39%	1.94%	0.93%	0.51%
Cooling factor: climate	11.99%	13.13%	15.9%	2.14%	0.85%	1.03%	1.16%	1.27%	1.54%	0.18%	0.19%	0.23%	0.59%	0.64%	0.78%	2.22%	1.6%	0.58%
Combined vintage, equipment saturation factors for heating																		
Heating factor, nat. gas: shade	21.57%	19.34%	15.00%	1.39%	12.25%	0.97%	1.84%	1.65%	1.28%	0.29%	0.26%	0.20%	0.54%	0.49%	0.38%	2.26%	1.09%	0.59%
Heating factor, electric: shade	0.15%	0.32%	0.90%	0.02%	0.06%	0.01%	0.01%	0.03%	0.08%	0.00%	0.00%	0.01%	0.00%	0.01%	0.02%	0.14%	0.07%	0.04%
Heating factor, nat. gas: climate	22.07%	19.79%	15.35%	3.95%	1.28%	0.99%	2.14%	1.91%	1.49%	0.32%	0.29%	0.23%	1.08%	0.97%	0.75%	2.60%	1.87%	0.68%
Heating factor, electric: climate	0.16%	0.32%	0.92%	0.03%	0.02%	0.06%	0.02%	0.03%	0.09%	0.00%	0.00%	0.01%	0.01%	0.02%	0.05%	0.16%	0.11%	0.04%

Multi-Family Residential Analysis

Unit energy consumptions (UECs) from shade for multi-family residences (MFRs) were calculated from single-family residential UECs adjusted by adjusted potential shade factors (APSFs) to account for reduced shade resulting from common walls and multi-story construction. Average potential shade factors were estimated from potential shade factors (PSFs), defined as ratios of exposed wall or roof (ceiling) surface area to total surface area, where total surface area includes common walls and ceilings between attached units in addition to exposed surfaces (Simpson 1998). A PSF=1 indicates that all exterior walls and roof are exposed and could be shaded by a tree, while PSF=0 indicates that no shading is possible (i.e., the common wall between duplex units). Potential shade factors were estimated separately for walls and roofs for both single and multi-story structures. Average potential shade factors were 0.74 for land use MFR 2-4 units and 0.41 for MFR 5+ units.

Unit energy consumptions were also adjusted for climate effects to account for the reduced sensitivity of multi-family buildings with common walls to outdoor temperature changes with respect to single-family detached residences. Since estimates for these PCFs were unavailable for multi-family structures, a multi-family PCF value of 0.80 was selected (less than single-family detached PCF of 1.0 and greater than small commercial PCF of 0.40; see next section).

Commercial and Other Buildings

Unit energy consumptions for commercial/industrial (C/I) and industrial/transportational (I/T) land uses due to presence of trees were determined in a manner similar to that used for multi-family land uses. Potential shade factors of 0.40 were assumed for small C/I, and 0.0 for large C/I. No energy impacts were ascribed to large C/I structures since they are expected to have surface to volume ratios an order of magnitude larger than smaller buildings and less extensive window area. Average potential shade factors for I/T structures were estimated to lie between these extremes; a value of 0.15 was used here. However, data relating I/T land use to building space conditioning were not readily available, so no energy impacts were ascribed to I/T structures. A multiple tree reduction factor of 0.85 was used and no benefit was assigned for shading of buildings on adjacent lots.

Potential climate factors of 0.40, 0.25 and 0.20 were used for small C/I, large C/I and I/T, respectively. These values are based on estimates by Akbari and others (1992) who observed that commercial buildings are less sensitive to outdoor temperatures than houses.

Change in UECs due to shade tend to increase with conditioned floor area (CFA) for typical residential structures. As building surface area increases so does the area shaded. This occurs up to a certain point because the projected crown area of a mature tree (approximately 700 to 3,500 ft^2 [65-325 m^2]) is often larger than the building surface areas being shaded. Consequently, more area is shaded with increased surface area. However, for larger buildings, a point is reached at which no additional area is shaded as surface area increases. Therefore, ??UECs will tend to diminish as CFA increases. Since information on the precise relationships between change in UEC, CFA, and tree size are not known, it was conservatively assumed that ??UECs don't change in Equation 1 for C/I and I/T land uses.

Atmospheric Carbon Dioxide Reduction

Sequestration (the net rate of CO_2 storage in above- and below-ground biomass over the course of one growing season) is calculated for each species using tree growth equations for DBH and height described earlier in this appendix (see Tree Growth Modeling) to calculate either tree volume or biomass. Equations from Pillsbury et. al (1998) are used when calculating volume. Fresh weight (kg/m^3) and specific gravity ratios from Alden (1995, 1997) are then applied to convert volume to biomass. When volumetric equations for urban trees are unavailable, biomass equations derived from data collected in rural forests are applied (Tritton and Hornbeck 1982; Ter-Mikaelian and Korzukhin 1997).

Carbon dioxide released through decomposition of dead woody biomass varies with characteristics of the wood itself, fate of the wood (e.g., amount left standing, chipped, or burned), and local soil and climatic conditions. Recycling of urban waste is now prevalent, and we assume here that most material is chipped and applied as landscape mulch. Calculations were conservative because they assume that dead trees are removed and mulched in the year that death occurs, and that 80% of their stored carbon is released to the atmosphere as CO_2 in the same year. Total annual decomposition is based on the number of trees in each species and age class that die in a given year and their biomass. Tree survival rate is the principal factor influencing decomposition. Tree mortality for Cheyenne was 2.0% for the first five years after out-planting and 0.8% every year thereafter, based on an average of the mortality rates, provided by the Urban Forester, unique to streets and parks (Olson, 2003). Finally, CO_2 released from tree maintenance was estimated to be 0.08 kg CO_2/cm DBH based on tree maintenance activities which release 2.59 kg CO_2/tree based on carbon dioxide equivalent annual release of 43,994 kg (4,792 gallons of gasoline and diesel fuel use) and average tree diameter of 31.8 cm (Olson 2003)

Avoided CO_2 Emissions Methodology

Reductions in building energy use result in reduced emissions of CO_2. Emissions were calculated as the product of energy use and CO_2 emission factors for electricity and heating. Heating fuel is largely natural gas and fuel oil in Cheyenne. The overall fuel mix for electrical generation provided from Xcel Energy was primarily coal (69%), natural gas (14%), and nuclear (11%) (U.S. EPA 2003).

Emissions factors for electricity lb/MWh) and natural gas (lb/MBtu) weighted by the appropriate fuel mixes are given in Table B-5. Implied value of avoided CO_2 was CA$0.0075/lb based on average high and low estimates for emerging carbon trading markets (CO2e.com 2002) (Table B-5). Values for criteria air pollutants were based on control-cost-based emissions for VOCs and damage-based emissions estimates for remaining pollutants using the methods of Wang and Santini (1995) (Table B-5). Emissions concentrations are from U.S. EPA (1998) and population estimates from the U.S. Census Bureau (2003)

	Emission Factor Electricity[a] (lb/MWh)	Natural gas[b] (lb/MBtu)	Implied value ($/lb)
CO_2	1,905	118	0.0075[c]
NO_2	3.440	0.0922	2.53
SO_2	6.890	0.0006	0.54
PM_{10}	0.776	0.0075	0.10
VOCs	0.735	0.0054	1.96

[a]U.S. Environmental Protection Agency (2003)
[b]U. S. Environmental Protection Agency 1998
[c]$15/ton for CO_2 (CO2e.com 2002)
[d]Wang and Santini (1995)

Table B-5. Emissions factors and implied values for CO_2 and criteria air pollutants.

Improving Air Quality

Avoided Emissions Methodology

Reductions in building energy use also result in reduced emissions of criteria air pollutants from power plants and space heating equipment. This analysis considered volatile organic hydrocarbons (VOCs) and nitrogen dioxide (NO_2)—both precursors of ozone (O_3) formation—as well as sulfur dioxide (SO_2) and particulate matter of <10 micron diameter (PM_{10}). Changes in average annual emissions and their offset values were calculated in the same way as for CO_2, again using utility-specific emission factors for electricity and heating fuels U.S. Environmental Protection Agency (2003).

Deposition and Interception Methodology

Trees also remove pollutants from the atmosphere. The hourly pollutant dry deposition per tree is expressed as the product of a deposition velocity $V_d = 1/(R_a+R_b+R_c)$, a pollutant concentration (C), a canopy projection (CP) area, and a time step. Hourly deposition velocities for each pollutant were calculated using estimates for the resistances R_a, R_b, and R_c estimated for each hour for a year using formulations described by Scott et al. (1998). Data from 2001 were selected as representative for modeling deposition based on a review of mean PM_{10} and ozone concentrations for years 1991-2002. Data for stations closest in proximity and climate to Cheyenne were used – PM_{10} from Cheyenne (Payton 2003), ozone from Fort Collins, and NO_2 and SO_2 from the Denver area (Adams county, Welby station [Hague 2003]).

Deposition was determined for deciduous species only when trees were in-leaf. A 50% re-suspension rate was applied to PM_{10} deposition. A combination of damage-based (SO_2, PM_{10}) and control-cost based (NO_2, O_3,) estimates for Cheyenne (population 53,000) were used to value emissions reductions (Wang and Santini 1995); NO_2 prices were used for ozone since ozone control measures typically aim at reducing NO_x. Hourly meteorological data for Cheyenne (air temperature, wind speed and precipitation) were used (National Climatic Data Center 2003), except for solar radiation, which came from Fort Collins (Colorado Agricultural Meteorological Network 2003).

BVOC Emissions Methodology

Emission of biogenic volatile organic carbon (sometimes called biogenic hydrocarbons or BVOCs) associated with increased ozone formation, were estimated for the tree canopy using methods described by McPherson et al. (1998). In this approach, the hourly emissions of carbon as isoprene and monoterpene are expressed as products of base emission factors and leaf biomass factors adjusted for sunlight and temperature (isoprene) or temperature (monoterpene). Hourly emissions were summed to get annual totals. This is a conservative approach, since we do not account for the benefit associated with lowered summertime air temperatures and the resulting reduced hydrocarbon emissions from biogenic as well as anthropogenic sources. The cost of these emissions is based on control cost estimates and was valued at $1.963.77/lb for Cheyenne (Wang and Santini 1995).

Reducing Storm-water Runoff and Hydrology

Storm-water Methodology

A numerical simulation model was used to estimate annual rainfall interception (Xiao et al. 1998). The interception model accounts for water intercepted by the tree, as well as throughfall and stem flow. Intercepted water is stored temporarily on canopy leaf and bark surfaces. Once the leaf is saturated, it drips from the leaf surface and flows down the stem surface to the ground or evaporates. Tree canopy parameters include species, leaf and stem surface area, shade coefficient (visual density of the crown), tree height, and foliation data. Tree height data were used to estimate wind speed at different heights above the ground and resulting rates of evaporation.

The volume of water stored in the tree crown was calculated from crown projection area (area under tree dripline), leaf area indices (LAI, the ratio of leaf surface area to crown projection area), and water depth on the canopy surface, while species-specific shade coefficients and tree surface saturation values influence the amount of projected throughfall. Hourly meteorological data for 1999 from CHEYENNE MINICIPAL AIRPORT (CYS) (latitude: 41°10' N; longitude: 104°49' W) were selected to best represent a typical meteorological year and, consequently, used for this simulation. Annual precipitation during 1999 was 16.1 inches (409.2 mm). A more complete description of the interception model can be found in Xiao et al. (1998).

To estimate the value of rainfall intercepted by urban trees, storm-water management control costs were used. The cost is estimated based on Cheyenne's annual budget of $1.5 million required to adequately maintain the city's storm-water infrastructure. Precipitation causes 4,446,904 cubic meters of runoff annually (USDA Soil Conservation Service, 1986). Total runoff is based on the distribution of land use and the soils water holding capacity. Total costs are divided by total runoff resulting in an average annual savings of $0.34/m^3 ($0.001).

Aesthetics & Other Benefits

Trees provide a host of aesthetic, social, economic, and health benefits that should be included in any benefit-cost analysis. One of the most frequently cited reasons that people plant trees is for beautification. Trees add color, texture, line, and form to the landscape. In this way, trees soften the hard geometry that dominates built environments. Research on the aesthetic quality of residential streets has shown that street trees are the single strongest positive influence on scenic quality (Schroeder and Cannon 1983). Consumer surveys have found that preference ratings increase with the presence of trees in the commercial streetscape. In contrast to areas without trees, shoppers indicated that they shop more often and longer in well-landscaped business districts, and were willing to pay more for goods and services (Wolf 1999).

Research in public housing complexes found that outdoor spaces with trees were used significantly more often than spaces without trees. By facilitating interactions among residents, trees can contribute to reduced levels of domestic violence, as well as foster safer and more sociable neighborhood environments (Sullivan and Kuo 1996).

Well-maintained trees increase the "curb appeal" of properties. Research comparing sales prices of residential properties with different tree resources suggests that people are willing to pay 3-7% more for properties with ample tree resources versus few or no trees. One of the most comprehensive studies of the influence of trees on residential property values was based on actual sales prices and found that each large front-yard tree was associated with about a 1% increase in sales price (Anderson and Cordell 1988). A much greater value of 9% ($15,000) was determined in a U.S. Tax Court case for the loss of a large black oak on a property valued at $164,500 (Neely 1988). Depending on average home sales prices, the value of this benefit can contribute significantly to cities' property tax revenues.

Scientific studies confirm our intuition that trees in cities provide social and psychological benefits. Humans derive substantial pleasure from trees, whether it is inspiration from their beauty, a spiritual connection, or a sense of meaning (Dwyer et al. 1992; Lewis 1996). Following natural disasters, people often report a sense of loss if the urban forest in their community has been damaged (Hull 1992). Views of trees and nature from homes and offices provide restorative experiences that ease mental fatigue and help people to concentrate (Kaplan & Kaplan 1989). Desk-workers with a view of nature report lower rates of sickness and greater satisfaction with their jobs compared to those having no visual connection to nature (Kaplan 1992). Trees provide important settings for recreation and relaxation in and near cities. The act of planting trees can have social value, for community bonds between people and local groups often result.

The presence of trees in cities provides public health benefits and improves the well being of those who live, work and recreate in cities. Physical and emotional stress has both short term and long-term effects. Prolonged stress can compromise the human immune system. A series of studies on human stress caused by general urban conditions and city driving show that views of nature reduce the stress response of both body and mind (Parsons et al. 1998). City nature also appears to have an "immunization effect," in that people show less stress response if they've had a recent view of trees and vegetation. Hospitalized patients with views of nature and time spent outdoors need less medication, sleep better, and have a better outlook than patients without connections to nature (Ulrich 1985). Trees reduce exposure to ultraviolet light, thereby lowering the risk of harmful effects from skin cancer and cataracts (Tretheway and Manthe 1999).

Certain environmental benefits from trees are more difficult to quantify than those previously described, but can be just as important. Noise can reach unhealthy levels in cities. Trucks, trains, and planes can produce noise that exceeds 100 decibels, twice the level at which noise becomes a health risk. Thick strips of vegetation in conjunction with landforms or solid barriers can reduce highway noise by 6-15 decibels. Plants absorb more high frequency noise than low frequency, which is advantageous to humans since higher frequencies are most distressing to people (Miller 1997).

Although urban forests contain less biological diversity than rural woodlands, numerous types of wildlife inhabit cities and are generally highly valued by residents. For example, older parks, cemeteries, and botanical gardens often contain a rich assemblage of wildlife. Street tree corridors can connect a city to surrounding wetlands, parks, and other greenspace resources that provide habitats that conserve biodiversity (Platt et al. 1994).

Urban and community forestry can provide jobs for both skilled and unskilled labor. Public service programs and grassroots-led urban and community forestry programs provide horticultural training to volunteers across the U.S. Also, urban and community forestry provides educational opportunities for residents who want to learn about nature through first-hand experience (McPherson and Mathis 1999). Local nonprofit tree groups, along with municipal volunteer programs, often provide educational materials, work with area schools, and hands-on training in the care of trees.

Property Value and Other Benefits Methodology

Many benefits attributed to urban trees are difficult to translate into economic terms. Beautification, privacy, shade that increases human comfort, wildlife habitat, sense of place and well-being are products that are difficult to price. However, the value of some of these benefits may be captured in the property values for the land on which trees stand. To estimate the value of these "other" benefits, results of research that compares differences in sales prices of houses are used to statistically quantify the difference associated with trees. The amount of difference in sales price reflects the willingness of buyers to pay for the benefits and costs associated with the trees. This approach has the virtue of capturing what buyers perceive to be as both the benefits and costs of trees in the sales price. Some limitations to using this approach in Cheyenne include the difficulty associated with 1) determining the value of individual street trees adjacent to private properties and 2) the need to extrapolate results from front yard trees on residential properties to street and park trees in various locations (e.g., commercial vs. residential).

In an Athens, GA study (Anderson and Cordell 1988), a large front yard tree was found to be associated with a 0.88% increase in average home resale values. Along with identifying the leaf surface area (LSA) of a typical mature large tree (30-year old Silver maple [*Acer saccharum*]) in Cheyenne (6,062 ft^2) and using the average annual change in LSA per unit area for trees within each DBH class as a resource unit, this increase was the basis for valuing the capacity of trees to increase property value.

Assuming the 0.88% increase in property value held true for the City of Cheyenne, each large tree would be worth $1,116 based on the median [2003] standard two-storey home sales price in Cheyenne ($115,254) (CNN Money 2003). However, not all trees are as effective as front yard residential trees in increasing property values. For example, trees adjacent to multifamily housing units will not increase the property value at the same rate as trees in front of a single-family home. Therefore, citywide street and park tree reduction factors (0.91 and 0.82, respectively) were applied to prorate trees' value based on the assumption that trees adjacent to differing land-use—single home residential, multi-home residential, commercial/industrial, vacant, park and institutional—were valued at 100%, 75%, 50%, 25%, 50%, and 50%, respectively, of the full $1,116 (McPherson et al. 2001). For this analysis, the reduction factor reflects Cheyenne land-use distributions and assumes an even tree distribution.

Given these assumptions, a typical large tree was estimated to increase property values by $0.30/ft^2 of LSA. For example, it was estimated that a single Silver maple tree adds about 137.8 ft^2 (12.8 m^2) of LSA per year when growing in the DBH range of 12-18 in (30.5-46.7 cm). Therefore, during this 12–18 inch period of growth silver maple trees effectively added $37.62, annually, to the value of an adjacent home, condominium, or business property (137.8 ft^2 x $0.30/$ft^2$ x 0.91% = $37.62).

ESTIMATING MAGNITUDE OF BENEFITS

Defined as *resource units*, the absolute value of the benefits of Cheyenne's street and park trees—electricity (kWh/tree) and natural gas savings (kBtu/tree), atmospheric CO_2 reductions (lbs/tree), air quality improvement (NO_2, PM_{10} and VOCs [lbs/tree]), storm-water runoff reductions (precipitation interception [ft^3/tree]) and property value increases (Δ LSA [ft^2/tree])—were assigned prices through methods described above for model trees.

Estimating the magnitude of benefits (resource units) produced by all street trees in Cheyenne required four procedures: 1) categorizing street trees by species and DBH based on the city's street tree inventory, 2) matching significant species with the growth models (those from the 6 modeled species in Cheyenne and the additional 16 modeled species in Fort Collins, CO that were adjusted to account for size differences between the two cities), 3) grouping remaining "other" trees by type, and 4) applying resource units to each tree.

Categorizing Trees by DBH Class

The first step in accomplishing this task involved categorizing the total number of street trees by relative age (DBH class). The inventory was used to group trees using the following classes:

1) 0-3 in (0-7.5 cm)
2) 3-6 in (7.6-15.1 cm)
3) 6-12 in (15.2-30.4 cm)
4) 12-18 in (30.5-45.6 cm)
5) 18-24 in (45.7-60.9 cm)
6) 24-30 in (61-76.2 cm)
7) 30-36 in (76.3-91.4cm)
8) 36-42 in (91.4-106.7 cm)
9) >42 in (106.7 cm)

Because DBH classes represented a range, the median value for each DBH class was determined and subsequently utilized as a single value representing all trees encompassed in each class. Linear interpolation was used to estimate resource unit values (Y-value) for each of the 22 modeled species for the 9 midpoints (X-value) corresponding to each of the DBH classes assigned to the city's street trees.

Applying Benefit Resource Units to Each Tree

Once categorized, the interpolated resource unit values were matched on a one-for-one basis. For example, out of the 226 inventoried American elms (*Ulmus americana*) citywide, 18 were within the 6-12 in (15.2-30.4 cm) DBH class size. The interpolated electricity and natural gas resource unit values for the class size midpoint (9 in [23 cm]) were 13.4kWh/tree and 367.4 kBtu/tree, respectively. Therefore, multiplying the size class resource units by 18 equals the magnitude of annual heating and cooling benefits produced by this segment of the population: 241.2 kWh in electricity saved and 6.61 MBtu natural gas saved.

Matching Significant Species with Modeled Species

To infer from the 22 municipal species modeled and adjusted for growth in Cheyenne to the inventoried street tree population, each species representing over 0.5% of the population was matched directly with corresponding model species. Where there was no corresponding tree, the best match was determined by identifying which of the 22 species was most similar in leaf shape/type, structure and habit.

Grouping Remaining "Other" Trees by Type

The species that were less than 0.5% of the population were labeled "other" and were categorized according to tree type classes based on tree type (one of two life forms and three mature sizes):

- Broadleaf deciduous - large (BDL), medium (BDM), and small (BDS).
- Coniferous evergreen - large (CEL)and small (CES).

Large, medium, and small trees measured >40 ft (12.2 m), 20-40 ft (60.1-12.2 m), and <20 ft (<6.1 m) in mature height, respectively. A typical tree was chosen for each of the above 12 categories to obtain growth curves for "other" trees falling into each of the categories:

BDL Other = Honeylocust (*Gleditsia triacanthos*)
BDM Other = Ornamental pear (*Pyrus sp.*)

BDS Other = Crabapple (*Malus sp.*)

CEL Other = Blue spruce (*Picea pungens*)

CES Other = scaled at 1/3 Ponderosa pine (*Pinus ponderosa*)

There were no medium-sized conifers listed in the Cheyenne inventory, nor were there broadleaf evergreen trees of any size.

CALCULATING NET BENEFITS AND BENEFIT-COST RATIO

It is impossible to quantify all the benefits and costs produced by trees. For example, property owners with large street trees can receive benefits from increased property values, but they may also benefit directly from improved human health (e.g., reduced exposure to cancer-causing UV radiation) and greater psychological well-being through visual and direct contact with trees. On the cost side, increased health care costs may be incurred because of nearby trees, as with allergies and respiratory ailments related to pollen. The value of many of these benefits and costs are difficult to determine. We assume that some of these intangible benefits and costs are reflected in what we term "property value and other benefits." Other types of benefits we can only describe, such as the social, educational, and employment/training benefits associated with the city's street tree resource. To some extent connecting people with their city trees reduces costs for health care, welfare, crime prevention, and other social service programs.

Cheyenne residents can obtain additional economic benefits from street trees depending on tree location and condition. For example, street trees can provide energy savings by lowering wind velocities and subsequent building infiltration, thereby reducing heating costs. This benefit can extend to the neighborhood, as the aggregate effect of many street trees reduces wind speed and reduces citywide winter energy use. Neighborhood property values can be influenced by the extent of tree canopy cover on streets. The community benefits from cleaner air and water. Reductions in atmospheric CO_2 concentrations due to trees can have global benefits.

Net Benefits and Costs Methodology

To assess the total value of annual benefits (*B*) for each park and street tree (*i*) in each management area (*j*) benefits were summed:

$$B = \sum_{1}^{n} j\left(\sum_{1}^{n} i\left(e_{ij} + a_{ij} + c_{ij} + h_{ij} + p_{ij}\right)\right) \quad \text{(Equation 3)}$$

where

e = price of net annual energy savings = annual natural gas savings + annual electricity savings

a = price of annual net air quality improvement = PM_{10} interception + NO_2 and O_3 absorption + avoided power plant emissions - BVOC emissions

c = price of annual carbon dioxide reductions = CO_2 sequestered less releases + CO_2 avoided from reduced energy use

h = price of annual stormwater runoff reductions = effective rainfall interception

p = price of aesthetics = annual increase in property value

Total net expenditures were calculated based on all identifiable internal and external costs associated with the annual management of municipal trees citywide. Annual costs for municipal (*C*) were summed:

$$C = p + t + r + d + e + s + c + l + a + q \quad \text{(Equation 4)}$$

where,

p = annual planting expenditure

t = annual pruning expenditure

r = annual tree and stump removal and disposal expenditure

d = annual pest and disease control expenditures

e = annual establishment / irrigation expenditure

s = annual price of repair / mitigation of infrastructure damage

c = annual price of litter / storm clean - up

l = average annual litigation and settlements expenditures due to tree - related claims

a = annual expenditure for program administration

q = annual expenditures for inspection / answer service requests

Total citywide annual net benefits as well as the benefit–cost ratio (BCR) were calculated using the sums of benefits and costs:

$$\text{Citywide Net Benefits} = B\text{-}C \quad \text{(Equation 5)}$$

$$\text{BCR} = B/C \quad \text{(Equation 6)}$$

ASSESSING STRUCTURE

Street tree inventory information, including species composition, DBH, health, total number of trees, were collected and analyzed using the City of Cheyenne’s 1992 Municipal Tree Inventory.

APPENDIX C: SPECIES CODE AND RELATIVE PERFORMANCE INDEX REFERENCE LIST

Common Name	Type	% of Trees in Each Condition Class Dead	Poor	Fair	Good	Excellent	RPI	No. of Trees	% of Total Population
Cottonwood/poplar	BDL	0.00	0.14	0.70	0.16	0.00	0.63	3,468	20.4%
Blue spruce	CEL	0.00	0.04	0.50	0.44	0.02	1.78	2,180	12.8%
Siberian elm	BDL	0.00	0.21	0.76	0.03	-	0.11	2,056	12.1%
Ponderosa/Austrian pine	CEL	0.00	0.03	0.42	0.55	0.00	2.23	1,710	10.1%
Green ash	BDL	0.00	0.15	0.64	0.20	0.00	0.82	1,358	8.0%
Honeylocust	BDL	0.00	0.09	0.71	0.19	0.00	0.78	787	4.6%
Crabapple	BDS	0.00	0.04	0.62	0.33	0.00	1.35	545	3.2%
Boxelder maple	BDL	-	0.29	0.67	0.04	-	0.15	468	2.8%
Juniper species	CES	-	0.05	0.64	0.31	-	1.26	439	2.6%
Willow	BDL	-	0.24	0.70	0.06	-	0.25	357	2.1%
Common chokecherry	BDS	0.01	0.08	0.53	0.37	0.01	1.51	316	1.9%
Pine	CEL	-	0.05	0.63	0.30	0.03	1.22	300	1.8%
American elm	BDL	0.01	0.20	0.72	0.07	-	0.28	276	1.6%
Quaking aspen	BDM	0.00	0.09	0.68	0.22	-	0.90	269	1.6%
Pinyon pine	CES	-	0.05	0.68	0.26	-	1.07	231	1.4%
Russian olive	BDS	0.00	0.11	0.45	0.43	-	1.76	210	1.2%
Hackberry	BDL	-	0.09	0.64	0.27	-	1.09	197	1.2%
Silver maple	BDL	0.01	0.12	0.79	0.08	-	0.33	194	1.1%
Fir	CEL	-	0.02	0.74	0.23	0.01	0.92	124	0.7%
Spruce	CEL	-	0.05	0.54	0.40	0.01	1.61	116	0.7%
Fruit	BDS	0.02	0.10	0.56	0.32	-	1.32	111	0.7%
Birch	BDM	0.02	0.06	0.66	0.26	-	1.06	111	0.7%
Littleleaf linden	BDL	-	0.06	0.43	0.51	-	2.07	104	0.6%
Locust	BDL	-	0.12	0.84	0.04	-	0.17	98	0.6%
White/silver poplar	BDL	-	0.16	0.72	0.12	-	0.48	93	0.5%
American linden	BDL	-	0.02	0.75	0.22	-	0.91	85	0.5%
Eastern red cedar	CES	-	0.08	0.64	0.29	-	1.17	80	0.5%
Douglas fir	CEL	-	0.10	0.65	0.24	-	0.99	78	0.5%
White oak	BDL	-	0.07	0.83	0.10	-	0.40	71	0.4%
Cherry/plum	BDS	0.01	0.20	0.46	0.32	-	1.29	69	0.4%
Mountain ash	BDS	-	0.12	0.67	0.22	-	0.88	69	0.4%
Hawthorn	BDS	-	0.09	0.77	0.14	-	0.59	69	0.4%
Apple	BDS	0.03	0.11	0.67	0.19	-	0.76	64	0.4%
Red oak	BDL	-	0.02	0.12	0.86	-	3.49	50	0.3%
Maple	BDL	-	0.06	0.78	0.17	-	0.68	36	0.2%
Buckthorn	BDS	-	0.11	0.89	-	-	-	27	0.2%
Norway maple	BDL	-	0.25	0.58	0.17	-	0.68	24	0.1%
Elm	BDL	-	0.04	0.96	-	-	-	24	0.1%
White cedar	CEL	-	0.09	0.57	0.26	0.09	1.06	23	0.1%
Buckeye	BDM	-	-	0.67	0.33	-	1.35	21	0.1%
Honeysuckle	BDS	-	-	0.95	0.05	-	0.20	20	0.1%
Silver buffaloberry	BDS	-	0.07	0.67	0.27	-	1.08	15	0.1%
Kentucky coffee tree	BDL	-	0.20	0.60	0.20	-	0.81	10	0.1%
Black walnut	BDL	-	-	0.90	0.10	-	0.41	10	0.1%
Viburnum	BDS	0.11	0.22	0.67	-	-	-	9	0.1%
Sumac	BDS	-	-	1.00	-	-	-	6	0.0%
Walnut	BDL	-	0.80	-	0.20	-	0.81	5	0.0%
Lombardy poplar	BDL	-	-	0.80	0.20	-	0.81	5	0.0%
Cherry	BDS	-	-	0.50	0.50	-	2.03	4	0.0%
Dogwood	BDS	-	0.50	0.50	-	-	-	4	0.0%
American sycamore	BDL	-	0.33	0.67	-	-	-	3	0.0%
Catalpa	BDL	-	0.50	0.50	-	-	-	2	0.0%
Hop Hornbeam	BDS	-	-	1.00	-	-	-	2	0.0%
Chinese lilac	BDS	-	-	1.00	-	-	-	2	0.0%
Yew	CES	-	-	1.00	-	-	-	2	0.0%
Redbud	BDS	1.00	-	-	-	-	-	1	0.0%
Mulberry	BDL	-	1.00	-	-	-	-	1	0.0%
Pear	BDM	-	-	1.00	-	-	-	1	0.0%

APPENDIX D: TOTAL STREET RIGHT-OF-WAY AND PARK TREE NUMBERS

RESIDENTIAL SOUTH OF PERSHING

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
Cottonwood/poplar	81	91	50	30	148	527	402	129	28	1,486
Siberian elm	187	83	70	195	273	164	54	13	4	1,043
Green ash	77	69	88	249	74	10	0	0	0	567
Honeylocust	32	64	37	139	23	6	0	0	0	301
Boxelder maple	76	26	39	76	37	3	1	0	0	258
American elm	14	6	14	46	34	11	1	2	0	128
Silver maple	11	11	17	35	23	20	7	2	0	126
Hackberry	7	0	12	42	13	0	0	0	0	74
BDL OTHER	83	56	26	50	13	10	10	3	1	252
Total	568	406	353	862	638	751	475	149	33	4,235
Medium Deciduous										
Quaking aspen	89	44	5	0	0	0	0	0	0	138
BDM OTHER	11	5	28	9	2	0	0	0	0	55
Total	100	49	33	9	2	0	0	0	0	193
Small Deciduous										
Crabapple	44	56	45	8	1	0	0	0	0	154
Common chokecherry	73	19	0	0	0	0	0	0	0	92
BDS OTHER	98	55	15	5	2	0	0	0	0	175
Total	215	130	60	13	3	0	0	0	0	421
Large Conifer										
Blue spruce	80	33	29	81	35	5	0	0	0	263
Ponderosa/Austrian pine	47	87	30	37	15	3	0	0	0	219
Pine	103	10	1	5	0	0	0	0	0	119
CEL OTHER	65	5	7	7	5	0	0	0	0	89
Total	295	135	67	130	55	8	0	0	0	690
Small Conifer										
Juniper species	52	14	9	2	0	0	0	0	0	77
CES OTHER	36	19	28	4	0	0	0	0	0	87
Total	88	33	37	6	0	0	0	0	0	164
Area 1 Total	1,266	753	550	1,020	698	759	475	149	33	5,703

DOWNTOWN

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
Honeylocust	8	72	57	35	11	0	0	0	0	183
Cottonwood/poplar	16	17	17	0	16	44	52	14	0	176
Green ash	23	45	36	42	17	1	0	0	0	164
Siberian elm	27	20	12	21	31	16	0	0	0	127
Boxelder maple	17	10	13	27	6	2	0	0	0	75
American elm	4	0	3	6	11	4	0	0	0	28
Hackberry	1	8	2	5	9	0	0	0	0	25
American linden	4	14	5	1	0	0	0	0	0	24
Littleleaf linden	5	7	2	5	0	0	0	0	0	19
BDL OTHER	15	8	6	7	4	1	0	0	0	41
Total	120	201	153	149	105	68	52	14	0	862
Medium Deciduous										
Quaking aspen	17	11	1	0	0	0	0	0	0	29
BDM OTHER	0	1	1	2	0	0	0	0	0	4
Total	17	12	2	2	0	0	0	0	0	33
Small Deciduous										
Common chokecherry	48	21	0	0	0	0	0	0	0	69
Crabapple	26	38	2	0	0	0	0	0	0	66
BDS OTHER	17	11	6	1	0	0	0	0	0	35
Total	91	70	8	1	0	0	0	0	0	170
Large Conifer										
Blue spruce	6	22	19	9	5	0	0	0	0	61
Ponderosa/Austrian pine	10	19	14	5	1	0	0	0	0	49
Pine	37	6	0	0	0	0	0	0	0	43
CEL OTHER	5	3	3	0	1	0	0	0	0	12
Total	58	50	36	14	7	0	0	0	0	165
Small Conifer										
Pinyon pine	14	35	3	1	0	0	0	0	0	53
Juniper species	8	7	3	1	0	0	0	0	0	19
CES OTHER	7	5	1	0	0	0	0	0	0	13
Total	29	47	7	2	0	0	0	0	0	85
Area 2 Total	315	380	206	168	112	68	52	14	0	1,315

RESIDENTIAL NORTH OF PERSHING

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
Cottonwood/poplar	21	4	8	14	71	164	97	34	3	416
Siberian elm	51	40	25	57	74	43	18	7	0	315
Green ash	35	23	50	123	32	0	0	0	0	263
Honeylocust	14	11	28	122	33	0	0	0	0	208
Boxelder maple	34	13	4	19	11	1	0	0	0	82
American elm	11	2	2	14	31	11	2	0	0	73
Silver maple	5	3	6	16	11	3	0	0	0	44
Hackberry	0	0	1	25	7	0	0	0	0	33
BDL OTHER	25	15	14	25	8	6	3	1	1	98
Total	196	111	138	415	278	228	120	42	4	1,532
Medium Deciduous										
Quaking aspen	42	33	4	0	0	0	0	0	0	79
Birch	4	9	12	13	2	0	0	0	0	40
BDM OTHER	0	1	0	1	0	0	0	0	0	2
Total	46	43	16	14	2	0	0	0	0	121
Small Deciduous										
Crabapple	14	15	44	5	0	0	0	0	0	78
Russian olive	7	3	10	10	2	0	0	0	0	32
Apple	13	8	4	3	0	0	0	0	0	28
Common chokecherry	18	6	0	0	0	0	0	0	0	24
Fruit	16	6	1	0	0	1	0	0	0	24
BDS OTHER	36	12	3	2	2	0	0	0	0	55
Total	104	50	62	20	4	1	0	0	0	241
Large Conifer										
Blue spruce	22	12	28	41	31	11	2	0	0	147
Pine	33	17	2	1	0	0	0	0	0	53
Ponderosa/Austrian pine	28	7	7	5	1	1	0	0	0	49
Fir	1	13	8	2	0	1	0	0	0	25
CEL OTHER	18	2	9	9	5	0	0	0	0	43
Total	102	51	54	58	37	13	2	0	0	317
Small Conifer										
Juniper species	29	24	4	1	0	0	0	0	0	58
Pinyon pine	8	13	16	1	0	0	0	0	0	38
Eastern red cedar	10	10	5	0	0	0	0	0	0	25
CES OTHER	1	0	0	0	0	0	0	0	0	1
Total	48	47	25	2	0	0	0	0	0	122
Res. No. of Pershing Tot.	496	302	295	509	321	242	122	42	4	2,333

JAYCEE PARK

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
Cottonwood/poplar	0	0	0	0	7	17	1	0	0	25
BDL OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	7	17	1	0	0	25
Medium Deciduous										
Quaking aspen	0	1	0	0	0	0	0	0	0	1
BDM OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	1	0	0	0	0	0	0	0	1
Small Deciduous										
Common chokecherry	4	0	0	0	0	0	0	0	0	4
Crabapple	2	0	0	0	0	0	0	0	0	2
Fruit	2	0	0	0	0	0	0	0	0	2
Cherry/plum	1	0	0	0	0	0	0	0	0	1
BDS OTHER	0	0	0	0	0	0	0	0	0	0
Total	9	0	0	0	0	0	0	0	0	9
Large Conifer										
Ponderosa/Austrian pine	0	0	1	4	3	0	0	0	0	8
Blue spruce	0	0	0	6	0	0	0	0	0	6
CEL OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	0	1	10	3	0	0	0	0	14
Small Conifer										
CES OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0
Jaycee Park Total	9	1	1	10	10	17	1	0	0	49

PIONEER PARK

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
Cottonwood/poplar	1	10	1	0	3	4	3	0	0	22
Honeylocust	0	5	0	0	0	0	0	0	0	5
Green ash	1	1	0	0	2	0	0	0	0	4
Littleleaf linden	0	2	0	0	0	0	0	0	0	2
Boxelder maple	0	0	1	0	0	0	0	0	0	1
BDL OTHER	0	0	0	0	0	0	0	0	0	0
Total	2	18	2	0	5	4	3	0	0	34
Medium Deciduous										
BDM OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0
Small Deciduous										
Crabapple	0	5	0	0	0	0	0	0	0	5
Common chokecherry	1	1	0	0	0	0	0	0	0	2
Fruit	1	0	0	0	0	0	0	0	0	1
BDS OTHER	0	0	0	0	0	0	0	0	0	0
Total	2	6	0	0	0	0	0	0	0	8
Large Conifer										
Fir	1	2	0	0	0	0	0	0	0	3
Blue spruce	0	2	1	0	0	0	0	0	0	3
Ponderosa/Austrian pine	0	0	0	1	0	0	0	0	0	1
Pine	1	0	0	0	0	0	0	0	0	1
CEL OTHER	0	0	0	0	0	0	0	0	0	0
Total	2	4	1	1	0	0	0	0	0	8
Small Conifer										
CES OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0
Pioneer Park Total	6	28	3	1	5	4	3	0	0	50

MARTIN LUTHER KING PARK

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
Honeylocust	1	8	0	0	0	0	0	0	0	9
Green ash	7	0	0	0	0	0	0	0	0	7
Cottonwood/poplar	0	4	0	0	2	0	0	0	0	6
Willow	1	0	2	1	0	0	0	0	0	4
Boxelder maple	0	0	1	0	1	1	0	0	0	3
BDL OTHER	0	1	0	0	0	0	0	0	0	1
Total	9	13	3	1	3	1	0	0	0	30
Medium Deciduous										
BDM OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0
Small Deciduous										
Crabapple	5	12	0	0	0	0	0	0	0	17
Cherry/plum	2	3	0	0	0	0	0	0	0	5
Common chokecherry	4	0	1	0	0	0	0	0	0	5
BDS OTHER	1	1	0	0	0	0	0	0	0	2
Total	12	16	1	0	0	0	0	0	0	29
Large Conifer										
Ponderosa/Austrian pine	0	8	29	0	0	0	0	0	0	37
Spruce	2	7	0	0	0	0	0	0	0	9
Fir	4	0	0	0	0	0	0	0	0	4
Blue spruce	3	0	0	0	0	0	0	0	0	3
Pine	3	0	0	0	0	0	0	0	0	3
CEL OTHER	0	0	0	0	0	0	0	0	0	0
Total	12	15	29	0	0	0	0	0	0	56
Small Conifer										
CES OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0
MLK Park Total	33	44	33	1	3	1	0	0	0	115

OPTIMIST PARK

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
Green ash	4	11	0	0	0	0	0	0	0	15
Littleleaf linden	0	1	0	0	0	0	0	0	0	1
BDL OTHER	0	0	0	0	0	0	0	0	0	0
Total	4	12	0	0	0	0	0	0	0	16
Medium Deciduous										
Buckeye	0	0	3	3	1	0	0	0	0	7
BDM OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	0	3	3	1	0	0	0	0	7
Small Deciduous										
Crabapple	0	3	0	0	0	0	0	0	0	3
Common chokecherry	0	1	0	0	0	0	0	0	0	1
BDS OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	4	0	0	0	0	0	0	0	4
Large Conifer										
Blue spruce	0	5	3	3	0	0	0	0	0	11
Ponderosa/Austrian pine	0	2	0	0	0	0	0	0	0	2
Fir	0	1	0	0	0	0	0	0	0	1
Pine	0	0	1	0	0	0	0	0	0	1
CEL OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	8	4	3	0	0	0	0	0	15
Small Conifer										
Juniper species	5	0	0	0	0	0	0	0	0	5
CES OTHER	0	0	0	0	0	0	0	0	0	0
Total	5	0	0	0	0	0	0	0	0	5
Optimist Park Total	9	24	7	6	1	0	0	0	0	47

TIMBERLAND PARK

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
Green ash	1	2	0	0	0	0	0	0	0	3
Honeylocust	2	1	0	0	0	0	0	0	0	3
American linden	0	1	1	0	0	0	0	0	0	2
Silver maple	0	0	0	1	0	0	0	0	0	1
BDL OTHER	0	0	0	0	0	0	0	0	0	0
Total	3	4	1	1	0	0	0	0	0	9
Medium Deciduous										
BDM OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0
Small Deciduous										
Fruit	1	4	0	0	0	0	0	0	0	5
Mountain ash	0	2	0	0	0	0	0	0	0	2
BDS OTHER	0	0	0	0	0	0	0	0	0	0
Total	1	6	0	0	0	0	0	0	0	7
Large Conifer										
Ponderosa/Austrian pine	0	2	3	1	0	0	0	0	0	6
Blue spruce	0	3	0	1	0	0	0	0	0	4
CEL OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	5	3	2	0	0	0	0	0	10
Small Conifer										
Pinyon pine	2	0	0	0	0	0	0	0	0	2
CES OTHER	0	0	0	0	0	0	0	0	0	0
Total	2	0	0	0	0	0	0	0	0	2
Timberland Park Total	6	15	4	3	0	0	0	0	0	28

CIVITAN PARK

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
BDL OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0
Medium Deciduous										
BDM OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0
Small Deciduous										
BDS OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0
Large Conifer										
Blue spruce	0	1	3	4	1	0	0	0	0	9
Ponderosa/Austrian pine	0	0	3	4	0	0	0	0	0	7
CEL OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	1	6	8	1	0	0	0	0	16
Small Conifer										
CES OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0
Civitan Park Total	0	1	6	8	1	0	0	0	0	16

LINCOLN PARK

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
Cottonwood/poplar	0	0	0	0	0	7	2	0	0	9
Green ash	2	3	0	2	1	0	0	0	0	8
Honeylocust	0	2	2	0	0	0	0	0	0	4
Maple	0	1	0	0	0	0	0	0	0	1
White oak	1	0	0	0	0	0	0	0	0	1
American linden	0	1	0	0	0	0	0	0	0	1
Littleleaf linden	0	1	0	0	0	0	0	0	0	1
American elm	0	0	0	0	1	0	0	0	0	1
BDL OTHER	0	0	0	0	0	0	0	0	0	0
Total	3	8	2	2	2	7	2	0	0	26
Medium Deciduous										
Birch	1	0	0	0	0	0	0	0	0	1
BDM OTHER	0	0	0	0	0	0	0	0	0	0
Total	1	0	0	0	0	0	0	0	0	1
Small Deciduous										
Fruit	0	6	0	0	0	0	0	0	0	6
Crabapple	0	4	0	0	0	0	0	0	0	4
BDS OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	10	0	0	0	0	0	0	0	10
Large Conifer										
Ponderosa/Austrian pine	0	9	24	1	0	0	0	0	0	34
CEL OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	9	24	1	0	0	0	0	0	34
Small Conifer										
CES OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0
Lincoln Park Total	4	27	26	3	2	7	2	0	0	71

UNITED NATIONS PARK

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
Hackberry	1	0	0	0	0	0	0	0	0	1
BDL OTHER	0	0	0	0	0	0	0	0	0	0
Total	1	0	0	0	0	0	0	0	0	1
Large Conifer										
Blue spruce	3	14	5	3	1	0	0	0	0	26
CEL OTHER	0	0	0	0	0	0	0	0	0	0
Total	3	14	5	3	1	0	0	0	0	26
United Nations Park Total	4	14	5	3	1	0	0	0	0	27

BRIMMER PARK

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
Locust	31	0	0	0	0	0	0	0	0	31
Honeylocust	0	21	2	0	0	0	0	0	0	23
Green ash	15	1	0	0	0	0	0	0	0	16
Cottonwood/poplar	6	2	1	0	0	0	0	0	0	9
Hackberry	1	3	0	0	0	0	0	0	0	4
BDL OTHER	2	0	0	0	0	0	0	0	0	2
Total	55	27	3	0	0	0	0	0	0	85
Small Deciduous										
Russian olive	11	1	0	0	0	0	0	0	0	12
Common chokecherry	9	0	0	0	0	0	0	0	0	9
Crabapple	1	2	1	0	0	0	0	0	0	4
BDS OTHER	0	2	0	0	0	0	0	0	0	2
Total	21	5	1	0	0	0	0	0	0	27
Large Conifer										
Ponderosa/Austrian pine	94	1	14	10	0	0	0	0	0	119
Blue spruce	17	3	3	2	0	0	0	0	0	25
Spruce	5	0	1	0	0	0	0	0	0	6
CEL OTHER	4	0	0	0	0	0	0	0	0	4
Total	120	4	18	12	0	0	0	0	0	154
Small Conifer										
Juniper species	58	1	0	0	0	0	0	0	0	59
Pinyon pine	7	6	1	0	0	0	0	0	0	14
CES OTHER	0	0	0	0	0	0	0	0	0	0
Total	65	7	1	0	0	0	0	0	0	73
Brimmer Park Total	261	43	23	12	0	0	0	0	0	339

CAHILL PARK

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
Siberian elm	1	27	25	6	0	0	0	0	0	59
Littleleaf linden	4	4	0	0	0	0	0	0	0	8
Cottonwood/poplar	0	4	3	0	0	0	0	0	0	7
Green ash	2	3	0	0	0	0	0	0	0	5
Honeylocust	4	1	0	0	0	0	0	0	0	5
BDL OTHER	0	0	0	0	0	0	0	0	0	0
Total	11	39	28	6	0	0	0	0	0	84
Small Deciduous										
Russian olive	27	0	0	0	0	0	0	0	0	27
BDS OTHER	1	0	0	0	0	0	0	0	0	1
Total	28	0	0	0	0	0	0	0	0	28
Large Conifer										
Blue spruce	35	10	12	2	0	0	0	0	0	59
Ponderosa/Austrian pine	11	12	2	6	0	0	0	0	0	31
CEL OTHER	1	0	0	0	0	0	0	0	0	1
Total	47	22	14	8	0	0	0	0	0	91
Small Conifer										
Pinyon pine	4	0	0	0	0	0	0	0	0	4
CES OTHER	1	0	0	0	0	0	0	0	0	1
Total	5	0	0	0	0	0	0	0	0	5
Cahill Park Total	91	61	42	14	0	0	0	0	0	208

MYLAR PARK

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
Willow	2	2	10	10	8	1	0	0	0	33
Cottonwood/poplar	6	10	8	1	0	0	0	0	0	25
Green ash	6	0	0	0	0	0	0	0	0	6
White/silver poplar	3	1	1	0	0	1	0	0	0	6
Silver maple	2	0	0	0	0	0	0	0	0	2
BDL OTHER	3	0	0	0	0	0	0	0	0	3
Total	22	13	19	11	8	2	0	0	0	75
Small Deciduous										
Fruit	22	0	0	0	0	0	0	0	0	22
Crabapple	10	3	0	0	0	0	0	0	0	13
Russian olive	7	0	1	1	0	0	0	0	0	9
Common chokecherry	4	0	0	0	0	0	0	0	0	4
BDS OTHER	0	0	0	0	0	0	0	0	0	0
Total	43	3	1	1	0	0	0	0	0	48
Large Conifer										
Blue spruce	17	4	14	1	0	0	0	0	0	36
Ponderosa/Austrian pine	2	2	9	1	0	0	0	0	0	14
Douglas fir	6	0	0	0	0	0	0	0	0	6
Fir	3	0	0	0	0	0	0	0	0	3
CEL OTHER	1	0	0	0	0	0	0	0	0	1
Total	29	6	23	2	0	0	0	0	0	60
Mylar Park Total	94	22	43	14	8	2	0	0	0	183

SMALLEY PARK

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
Green ash	2	0	0	0	0	0	0	0	0	2
Honeylocust	2	0	0	0	0	0	0	0	0	2
Maple	1	0	0	0	0	0	0	0	0	1
Willow	0	0	0	1	0	0	0	0	0	1
BDL OTHER	0	0	0	0	0	0	0	0	0	0
Total	5	0	0	1	0	0	0	0	0	6
Small Deciduous										
Common chokecherry	2	0	0	0	0	0	0	0	0	2
Crabapple	1	0	0	0	0	0	0	0	0	1
BDS OTHER	0	0	0	0	0	0	0	0	0	0
Total	3	0	0	0	0	0	0	0	0	3
Large Conifer										
Blue spruce	7	0	0	0	0	0	0	0	0	7
Douglas fir	1	0	0	0	0	0	0	0	0	1
CEL OTHER	0	0	0	0	0	0	0	0	0	0
Total	8	0	0	0	0	0	0	0	0	8
Smalley Park Total	16	0	0	1	0	0	0	0	0	17

HOLIDAY PARK

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
Cottonwood/poplar	18	10	32	163	70	50	49	19	11	422
Willow	1	2	32	73	56	26	8	2	0	200
Green ash	22	6	1	0	0	0	0	0	0	29
Siberian elm	1	1	4	6	9	2	1	0	0	24
Littleleaf linden	14	4	0	0	0	0	0	0	0	18
Hackberry	7	4	0	1	0	0	0	0	0	12
American elm	0	0	2	6	4	0	0	0	0	12
BDL OTHER	8	5	7	3	0	1	0	0	0	24
Total	71	32	78	252	139	79	58	21	11	741
Medium Deciduous										
BDM OTHER	1	0	0	0	0	0	0	0	0	1
Total	1	0	0	0	0	0	0	0	0	1
Small Deciduous										
Common chokecherry	32	2	0	0	0	0	0	0	0	34
Crabapple	24	1	1	0	0	0	0	0	0	26
Hawthorn	0	3	16	0	0	0	0	0	0	19
Russian olive	6	6	0	1	0	0	0	0	0	13
BDS OTHER	8	0	0	0	0	0	0	0	0	8
Total	70	12	17	1	0	0	0	0	0	100
Large Conifer										
Blue spruce	8	2	8	24	4	1	1	0	0	48
Ponderosa/Austrian pine	0	3	7	13	2	0	0	0	0	25
Pine	13	2	0	0	0	0	0	0	0	15
CEL OTHER	11	2	0	0	0	0	0	0	0	13
Total	32	9	15	37	6	1	1	0	0	101
Small Conifer										
Juniper species	0	3	23	2	0	0	0	0	0	28
CES OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	3	23	2	0	0	0	0	0	28
Holiday Park Total	174	56	133	292	145	80	59	21	11	971

LIONS PARK

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
Siberian elm	9	28	180	117	39	11	4	0	0	388
Cottonwood/poplar	13	6	22	38	98	111	58	16	0	362
Green ash	21	11	38	45	2	0	0	0	0	117
Willow	1	3	19	32	24	9	3	1	0	92
White oak	39	2	0	0	0	0	0	0	0	41
Red oak	40	0	0	0	0	0	0	0	0	40
Boxelder maple	11	10	5	4	0	0	0	0	0	30
BDL OTHER	21	11	31	17	8	7	6	2	0	103
Total	155	71	295	253	171	138	71	19	0	1,173
Medium Deciduous										
BDM OTHER	18	0	4	3	0	0	0	0	0	25
Total	18	0	4	3	0	0	0	0	0	25
Small Deciduous										
Crabapple	79	11	23	5	0	0	0	0	0	118
Common chokecherry	27	6	1	1	0	0	0	0	0	35
Hawthorn	6	18	6	0	0	0	0	0	0	30
BDS OTHER	23	5	8	6	2	0	0	0	0	44
Total	135	40	38	12	2	0	0	0	0	227
Large Conifer										
Ponderosa/Austrian pine	92	12	211	399	86	12	1	0	0	813
Blue spruce	19	14	97	195	49	2	0	0	0	376
Fir	38	0	0	0	0	0	0	0	0	38
Douglas fir	13	0	8	8	2	0	0	0	0	31
CEL OTHER	5	0	3	0	0	0	0	0	0	8
Total	167	26	319	602	137	14	1	0	0	1,266
Small Conifer										
Juniper species	6	20	30	2	0	0	0	0	0	58
CES OTHER	1	0	5	0	0	0	0	0	0	6
Total	7	20	35	2	0	0	0	0	0	64
Lions Park Total	482	157	691	872	310	152	72	19	0	2,755

AIRPORT GOLF COURSE

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
Cottonwood/poplar	41	27	46	52	110	51	25	6	0	358
Siberian elm	7	13	4	4	4	2	0	1	0	35
Green ash	5	4	5	1	0	0	0	0	0	15
Honeylocust	0	0	8	5	0	0	0	0	0	13
American elm	2	4	2	2	3	0	0	0	0	13
BDL OTHER	1	5	4	2	1	1	0	0	0	14
Total	56	53	69	66	118	54	25	7	0	448
Small Deciduous										
Crabapple	20	1	2	0	0	0	0	0	0	23
BDS OTHER	14	4	5	2	1	0	0	0	0	26
Total	34	5	7	2	1	0	0	0	0	49
Large Conifer										
Blue spruce	75	50	72	75	22	0	0	0	0	294
Ponderosa/Austrian pine	10	16	58	55	22	1	0	0	0	162
Fir	4	0	1	9	0	0	0	0	0	14
Spruce	0	0	11	3	0	0	0	0	0	14
CEL OTHER	1	0	0	1	0	0	0	0	0	2
Total	90	66	142	143	44	1	0	0	0	486
Small Conifer										
Pinyon pine	0	55	2	0	0	0	0	0	0	57
Juniper species	0	10	8	2	0	0	0	0	0	20
CES OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	65	10	2	0	0	0	0	0	77
Airport Golf Course Total	180	189	228	213	163	55	25	7	0	1,060

PRAIRIE VIEW GOLF COURSE

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
Green ash	121	2	0	0	0	0	0	0	0	123
Cottonwood/poplar	75	0	7	1	0	0	0	0	0	83
Siberian elm	3	16	23	3	0	0	0	0	0	45
Hackberry	14	0	0	0	0	0	0	0	0	14
BDL OTHER	0	1	0	0	0	0	0	0	0	1
Total	213	19	30	4	0	0	0	0	0	266
Small Deciduous										
Russian olive	55	1	0	0	0	0	0	0	0	56
BDS OTHER	7	1	0	0	0	0	0	0	0	8
Total	62	2	0	0	0	0	0	0	0	64
Large Conifer										
Blue spruce	69	24	51	9	0	0	0	0	0	153
Ponderosa/Austrian pine	33	3	29	4	0	0	0	0	0	69
Pine	28	0	4	2	1	0	0	0	0	35
Fir	7	0	0	0	0	0	0	0	0	7
CEL OTHER	3	3	0	0	0	0	0	0	0	6
Total	140	30	84	15	1	0	0	0	0	270
Small Conifer										
CES OTHER	5	0	0	0	0	0	0	0	0	5
Total	5	0	0	0	0	0	0	0	0	5
Prairie View Golf Course	420	51	114	19	1	0	0	0	0	605

CHEYENNE CEMETERY

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
Cottonwood/poplar	2	1	2	9	8	8	13	4	6	53
Siberian elm	9	0	0	0	2	3	4	0	2	20
Green ash	4	0	5	1	2	1	1	0	0	14
Boxelder maple	6	0	3	0	0	2	0	0	0	11
BDL OTHER	10	5	4	2	2	2	0	0	0	25
Total	31	6	14	12	14	16	18	4	8	123
Medium Deciduous										
BDM OTHER	17	0	0	0	0	0	0	0	0	17
Total	17	0	0	0	0	0	0	0	0	17
Small Deciduous										
Common chokecherry	22	3	0	0	0	0	0	0	0	25
Crabapple	3	10	11	0	0	0	0	0	0	24
Mountain ash	11	2	5	2	1	0	0	0	0	21
Cherry/plum	4	4	6	0	0	0	0	0	0	14
BDS OTHER	6	2	0	0	0	0	0	0	0	8
Total	46	21	22	2	1	0	0	0	0	92
Large Conifer										
Blue spruce	16	16	184	155	169	99	10	0	0	649
Ponderosa/Austrian pine	7	1	5	29	8	0	0	0	0	50
Pine	4	2	2	6	4	1	0	0	0	19
CEL OTHER	1	0	1	3	5	1	0	0	0	11
Total	28	19	192	193	186	101	10	0	0	729
Small Conifer										
Juniper species	16	40	49	10	0	0	0	0	0	115
CES OTHER	4	3	0	0	0	0	0	0	0	7
Total	20	43	49	10	0	0	0	0	0	122
Cheyenne Cemetery Total	142	89	277	217	201	117	28	4	8	1,083

BAR X

Species	DBH (in)									
	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total
Large Deciduous										
Cottonwood/poplar	0	9	0	0	0	0	0	0	0	9
Kentucky coffee tree	0	2	0	0	0	0	0	0	0	2
BDL OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	11	0	0	0	0	0	0	0	11
Medium Deciduous										
Quaking aspen	0	3	0	0	0	0	0	0	0	3
BDM OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	3	0	0	0	0	0	0	0	3
Small Deciduous										
Crabapple	0	6	0	0	0	0	0	0	0	6
BDS OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	6	0	0	0	0	0	0	0	6
Large Conifer										
Ponderosa/Austrian pine	0	15	0	0	0	0	0	0	0	15
CEL OTHER	0	0	0	0	0	0	0	0	0	0
Total	0	15	0	0	0	0	0	0	0	15
Bar X Total	0	35	0	0	0	0	0	0	0	35