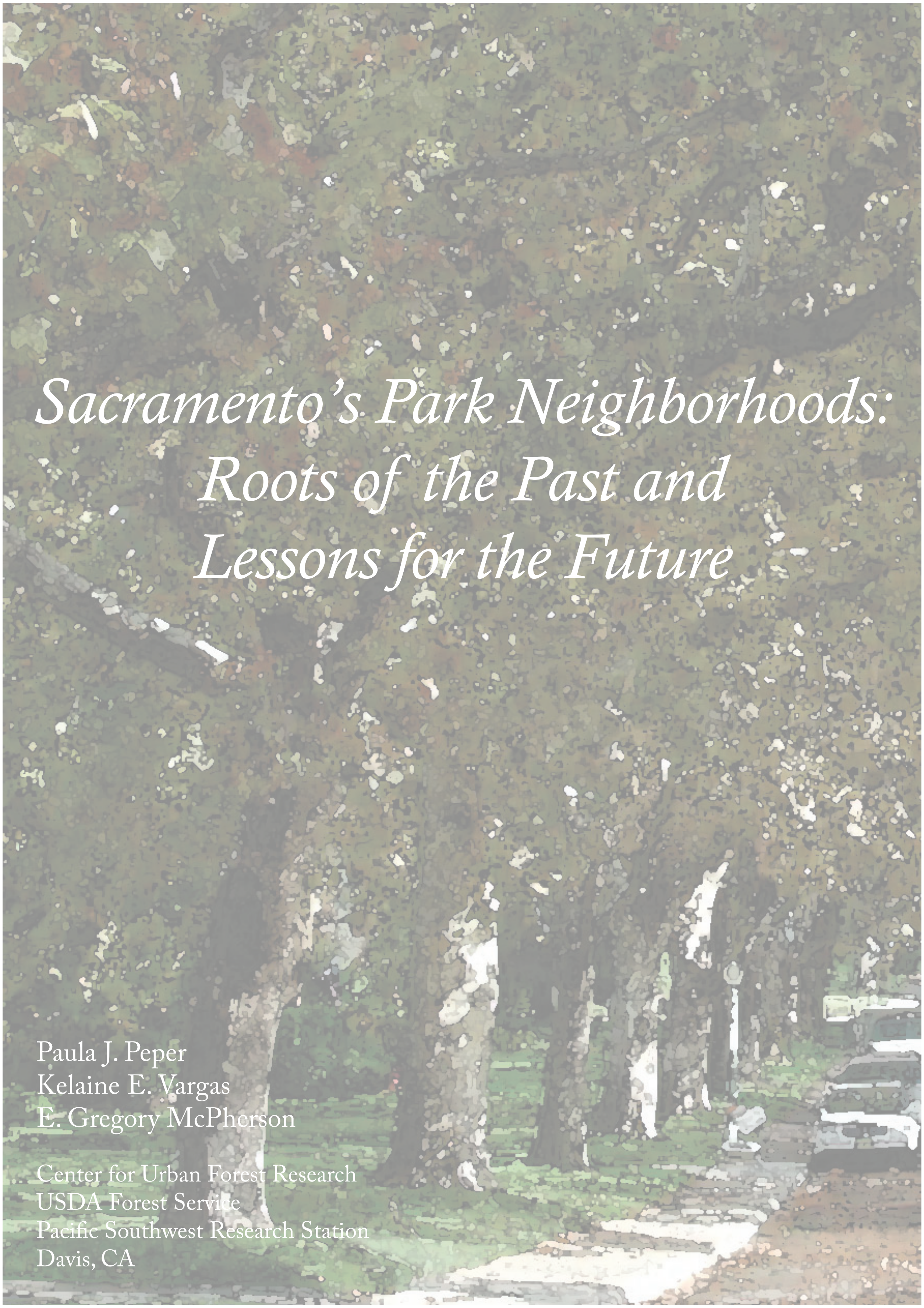

Sacramento's Park Neighborhoods: Roots of the Past and Lessons for the Future

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Executive Summary

In every city, there are neighborhoods, like the park neighborhoods of Sacramento, that have stood the test of time; sought-after places where, decade after decade, families and individuals have chosen to make their homes. The goal of the first part of this study was to consider the role that trees have in creating this atmosphere. What kinds of trees were planted long ago and which have survived? How have they grown and what factors have influenced them over time? What is their relationship with the built environment they have been placed in?

At the same time, designs for the neighborhoods of today must address the needs of the present. We ask that they be not only beautiful, but also healthy and environmentally valuable. Trees have a role to play in accomplishing this as well. The goal of the second part of this study was to consider the many benefits that trees provide and to suggest ways to maximize them through design.

For the first part of the study, we began by assessing the five park neighborhoods of Sacramento – Oak Park, Curtis Park, McKinley Park, East Sacramento, and Land Park – through a broad "windshield" survey to determine species dominance, age, and general planting patterns. Representative street sections were chosen for more in-depth analysis. Data collected included tree species; diameter at breast height; tree height and crown diameter; estimated age; lot, structure, sidewalk, street, and curb and gutter widths; setback from tree to nearest pavement, to nearest structure, and to lot line; azimuth from tree to nearest conditioned structure; damage to sidewalks and driveways related to trees; and tree condition.

By far the most common species was the planetree (*Platanus* spp.), which represented more than half of all trees studied. Historical records show that several species, including *P. orientalis*, *P. occidentalis*, and *P. acerifolia,* have been planted over the years. Fifty-eight species comprise the other half of the plantings with the next most predominant being red maple (*Acer rubrum*), American elm (*Ulmus americana*), sweetgum (*Liquidambar styraciflua*), and deodar cedar (*Cedrus deodora*).

Along representative streets, average tree size was a remarkable 33 inches in diameter at breast height, 78 ft in height, and 60 ft in crown diameter. The trees often dwarf the residences and provide a distinct sense of living in a peaceful, forested landscape. House setbacks from these large trees ranged from 9 to 67 ft with average setback of 26 ft. The setback for trees to the nearest hardscape (sidewalk, curb or gutter) ranged from 2.5 to 19 ft with an average setback of 5.4 ft.

There were two main planting configurations for treescapes. (1) Trees were planted in planting strips located between the curb and sidewalk. Planting strips ranged in width from 4.5 ft to 15 ft. (2) Sidewalks were immediately adjacent to the curb, and trees were planted directly in the front lawn. Where trees were planted in planting strips, on average there were more trees per residence, but fewer survived from the original plantings, and many in the smallest strips were stunted. The size of the planting space was also correlated with the amount of adjacent sidewalk damage, with trees within 2–4 ft of sidewalks causing damage in 86% of cases and trees 10–12 ft from pavement not being associated with any damage.

The pattern emerging from this study was trees planted in larger spaces were larger and lived longer.

In the second part of the study, we began by looking at the ecosystem services that trees provide, including energy conservation, air pollutant and greenhouse gas reductions, and stormwater management.

For three land use types – residential areas, commercial districts and parking lots, and transportation corridors – we considered the most relevant and feasible ecosystem services that could be provided and suggested ways to maximize these. Recommendations that held true across the land use types included the following:

- Plant the largest tree possible for the available growing space.
- Concentrate planting efforts on the western and eastern sides of buildings.
- Select species with large leaf surface area, long leaf stems, hairy plant parts, and rough bark to intercept more air pollutants and more rainfall.
- Wherever possible, treat the tree and the soil it is planted in as a mini-stormwater reservoir to maximize rainfall interception.
- Provide each tree with the best possible planting conditions, including an adequate volume of good quality soil, and the best early care to set it on the path to a healthy and long life.
- Allow for age and species diversity at the large scale to protect the urban forest against threats from disease and pests.
- Where trees are planted close together to maximize early canopy, a management plan should consider recommendations for removal once trees begin to impinge on each other.

By studying the patterns of planting and survival over the past 100 years, we have uncovered a great wealth of information about how a sustainable urban forest grows – how much space trees need to reach their full potential, which species stand the test of time, how trees and homes work together to create a forested atmosphere. By combining the historic data with current knowledge about the ecosystem services trees provide and how we can best maximize those benefits, we have the opportunity to create new neighborhoods that offer the best of both worlds: the historic grace of the past and the environmental values of the present.

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Section I: The Treescape of Sacramento's Park Neighborhoods

Introduction

In every city, there are neighborhoods, like the park neighborhoods of Sacramento, that have stood the test of time; sought-after places where, decade after decade, families and individuals have chosen to make their homes. Although all cities and neighborhoods evolve as the years go by, changing with the fashions of the day, adapting to outside influences – positive or negative – some retain a character that makes them places where we still want to put down roots. Some have a past that indicates the promise of a bright future. The goal of the first part of this study was to consider the role that trees have in creating this atmosphere. What kinds of trees were planted long ago and which have survived? How have they grown and what factors have influenced them over time? What is their relationship to the built environment they have been placed in? We hope that by answering these questions we can learn something about creating magical places for the future.

At the same time, designs for the neighborhoods of today must address the needs of the present. We ask that they be not only beautiful, but also healthy and environmentally valuable. Trees have a role to play in accomplishing this as well. The goal of the second part of this study was to consider the many benefits that trees provide and to suggest ways to maximize them through design.

The Park Neighborhoods of Sacramento

In the late 1800s residential neighborhoods in the city of Sacramento were limited to the areas currently referred to as "downtown" and "midtown." Little beyond farms, ranches, dairies, orchards and open land existed beyond 31st and Y Streets to the east and south or North B Street and the American River to the north and west. Development immediately outside the Sacramento city boundary began in the late 1880s with the extension of railroads to southern California; with this, Sacramento became a central hub for rail traffic. The introduction of citrus crops and increasing markets for other fruit crops contributed to a rapidly increasing population. New neighborhoods begun in the 1880s – Oak Park and Curtis Park – were among the nation's first "streetcar suburbs." Peaceful country living and inexpensive transportation to downtown areas (5 cents per ride) were selling points for these two neighborhoods and for the subsequent Land Park, McKinley Park and East Sacramento developments.

As historian Dan Murphy (2005) points out in *Images of America: Sacramento's Curtis Park*, "An organizing framework for any suburban history is the effect of advances in transportation technology and infrastructure on the landscape." Curtis and Oak Park landscapes in particular have been affected by transportation transitions for more than 100 years – from horse, buggy, and wagon, to train and trolley, and finally to car and truck. Each of these changes had effects on the treescape as well.

With the exception of Oak Park, all of these suburbs remained desirable neighborhoods despite the fact that trolley service ended, transportation corridors changed, and the city's downtown core suffered a long period of urban decay. Lots in East Sacramento's Fab Forties neighborhood that originally sold for as little as $150 currently sell for $800,000 to $1.5 million. In Curtis Park, homes on lots originally advertised for $700 now sell for nearly $500,000. Real estate values have increased similarly in McKinley and Land Park. For a variety of reasons, Oak Park, the oldest of the Streetcar Suburbs, has not enjoyed the consistent success known by the other neighborhoods. After the closing of Joyland in 1927, an amusement park central to the neighborhood, a slow downward spiral into urban decay began, increased by the construction of two freeways and unsuccessful attempts by the City of Sacramento to rejuvenate the commercial district. Only recently has the area begun to revive due primarily to efforts of residents and neighborhood associations.

The primary objective of this study was to conduct an analysis of the streetscape of Sacramento's historic park neighborhoods. Our focus was to assess how tree health, growth, and survival differed across typical neighborhood streetscapes and to evaluate the contribution trees have had in either the continued success or the rejuvenation of these neighborhoods. A second objective was to discover trends within these communities to determine key design and management concepts for developing multifunctional, sustainable new communities.

Methods

City plat maps were obtained and a windshield survey conducted of neighborhood streets to assess species and dominance. Diagrams of representative street profiles for the five neighborhoods were used to select street segments for more intensive sampling. Predominantly, the sampled segments represented those in each neighborhood with large, long-established trees – those that are most desired and that provide the most benefits. This provided the opportunity to assess structure and sustainability of large trees as well as related hardscape and management issues over time. A total of 24 street segments were visited in the field, with the number per neighborhood based on both size of the neighborhood and number of overall street design types (Table 1).

Data collected for each street segment included number of street trees, tree species, spacing between trees, street width, curb and gutter width, and planting strip width (if present). Additionally, lots were randomly selected for intensive sampling. Data collected on these lots included lot width, structure width, tree setback from curb, tree setback from residence, tree diameter-at-breast height (DBH, in inches), total tree height, crown diameters parallel and

Table 1— Street segments where treescapes were intensively sampled

Neighborhood	Street	Segment
Curtis Park	7th St.	24th and West
Curtis Park	Castro Way	2600-2661
Curtis Park	Donner Way	2400-2600
Curtis Park	Portola Way	24th and 26th
East Sacramento	51st St.	M and Folsom
East Sacramento	46th St.	J and Folsom
East Sacramento	46th St.	J and Folsom
East Sacramento	45th St.	J and Folsom
East Sacramento	44th St.	J and Folsom
East Sacramento	40th St.	Folsom and R
East Sacramento	38th St.	Folsom and R
Land Park	5th St.	17th and 19th
Land Park	Weller Way	Land Park and Govan
Land Park	Harkness St.	Larkin and Burnett
Land Park	Land Park Dr.	Markham and 2nd
Land Park	Perkins	Govan and Riverside
McKinley Park	D St.	33rd and Alhambra
McKinley Park	37th St.	H and F
Oak Park	Broadway - median	36th and 35th
Oak Park	Broadway	36th and 35th
Oak Park	1st Ave	39th and 37th
Oak Park	35th St.	T and V
Oak Park	X St.	32nd and 34th
Oak Park	1st Ave	35th and 34th

perpendicular to the street, foliar and woody condition, location of tree on lot (measured from lot line in two directions), tree orientation in relationship to nearest adjacent structure, infrastructure damage associated with tree (sidewalk, curb, gutter, driveway), wire and other utility conflicts. All dimensional measurements were in English units, using inches for DBH and feet for all remaining dimensions.

Sources for historical information are cited throughout this report, including interviews with residents, commercial and city arborists, newspaper articles and web site information.

Trees are described throughout this document as small, medium, or large. These categories indicate tree height at maturity with small, medium, and large equaling 0–30, 30–50, and over 50 ft, respectively.

Results

Data collected along representative streets with mature trees indicate an average trunk diameter of 33 inches, with average height and crown diameters of 78 and 60 ft, respectively. The trees often dwarf the residences and provide a distinct sense of living in a peaceful, forested landscape. House setbacks from these large trees ranged from 9 to 67 ft with average setback at 26 ft. The setback for trees to the nearest hardscape (sidewalk, curb or gutter) ranged from 2.5 to 19 ft with an average setback of 5.4 ft.

Treescapes along the studied streets fell into two broad categories: those with planting strips (Fig. 1) and those without (Fig. 2). Figures 1 and 2 illustrate the typical conditions present for each of the street sections. Planting strip widths ranged from 5 to 15 ft, with typical setbacks between house and sidewalk of 12.5 to 36.5 ft. Typical setbacks for lots without planting strips ranged from 15.5 to 45.5 ft.

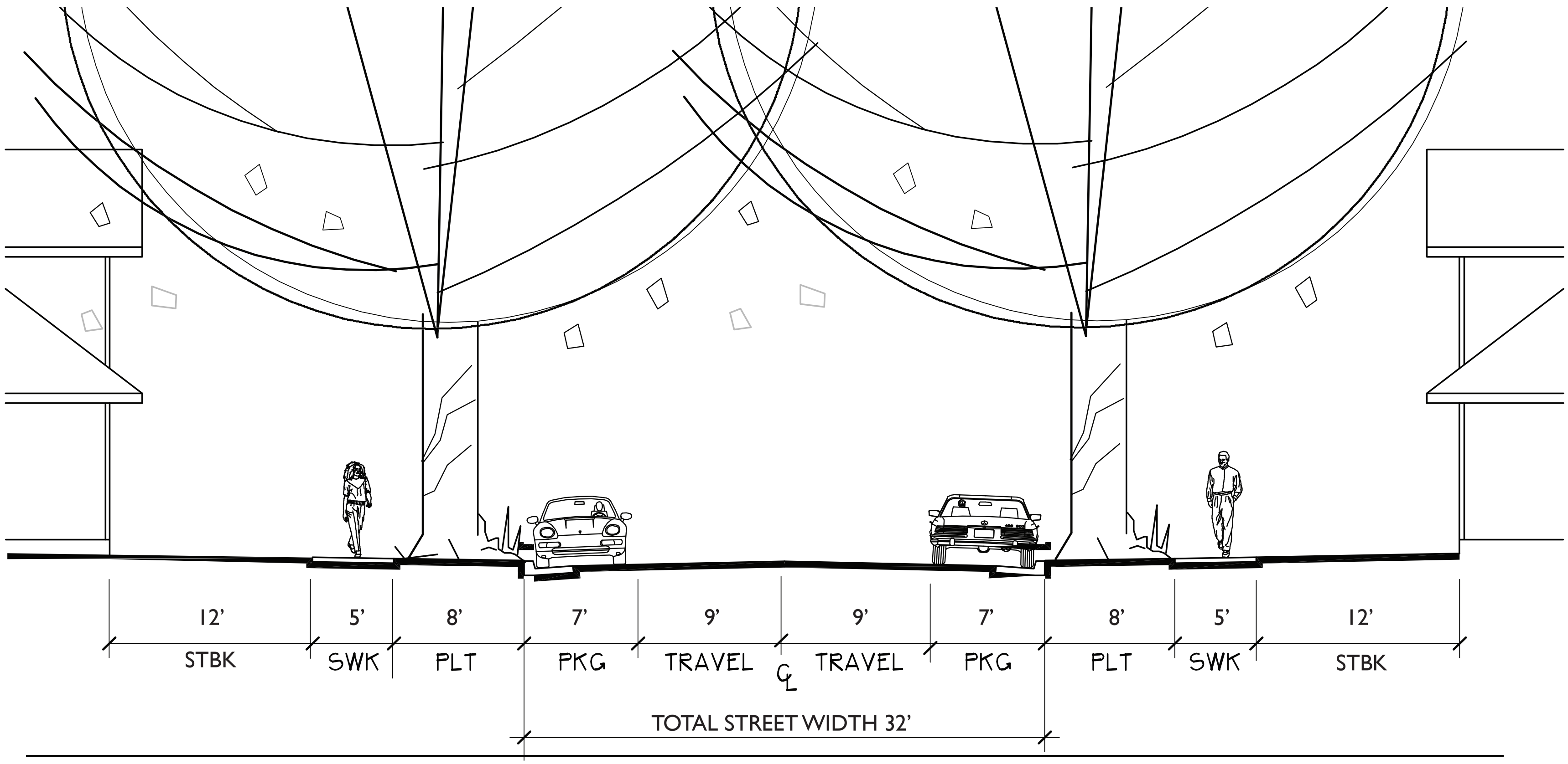
Oak Park

Neighborhood Overview

Oak Park was the first streetcar suburb proffered by developers in Sacramento. Auctions of its first lots preceded those in Curtis Park by a month. Oak Park is bounded by V Street or Highway 50 to the North, Franklin Boulevard (originally) or Highway 99 to the West, Stockton Boulevard to the east, and depending on source, 8th and 9th Streets or 14th Street or Fruitridge Road to the south.

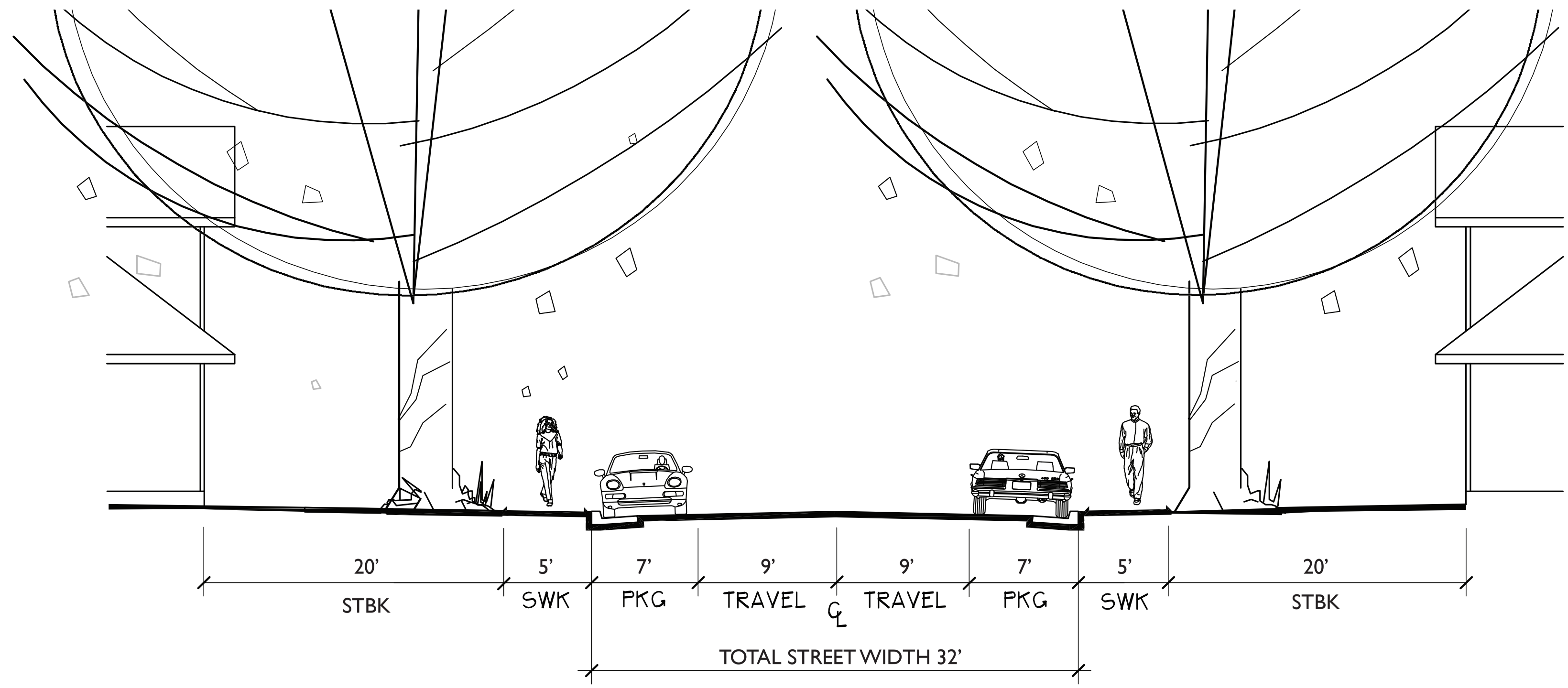
In its early days Oak Park was sold to prospective home and business owners as the "Eden of California," in part due to the promise of trees. Although parcels were initially auctioned as early as 1887, most remained vacant until after the turn of the 20th century. The community was developed as a working class, commuter neighborhood. Developer Edwin Alsip advertised that among Oak Park's attractions were no city taxes and broad, graded avenues lined with semi-tropical fruit trees (Simpson 2004). Early photos show none of the promised tropical trees other than date palms (*Phoenix canariensis*), but citrus trees (*Citrus* spp.) are commonly found today near older homes north of Broadway and 3rd Avenue. In the 1880s, 1st Avenue was named Orange Avenue and orange groves bordered parts of the developing neighborhood. In 1911, the city annexed Oak Park. Although its tax-free days were over, the community experienced an economic boom after annexation. More businesses were built in its growing commercial district, and this brought new residents who worked in the businesses and for the railroad.

Still, infill within neighborhood boundaries and individual tracts remained sporadic. To this day there remain empty parcels along many streets, and development dates for homes in the historic Trolley Car District (much of the area first sold by Alsip in 1887) range from the 1890s to 1990 (City of Sacramento 2007). This also explains the wide range of tree ages throughout the community. Few streets have one predominant species or trees of one age running the entire length. There are blocks where early developers or homeowners planted a particular species, but the majority of Oak Park has neither uniform



			Planting strip									
			Section							Tree		
Neighborhood	Street	Between	PUE	SWK	PLT	Total street width	PLT	SWK	PUE	DBH	Height	Crown diameter
Curtis Park	Donner, N side		15.5	4.5	5	33	5	4.5	15.5	24	53	41
Curtis Park	Portola		12.5	5	5	41	5	5	12.5	22	50	43
Land Park	5th	17th and 19th	24.5	4	9	30	9	4	24.5	25	69	49
McKinley	D	33rd and Alhambra	19	6	15	33	15	6	19	30	85	57.5
McKinley	37th	H and F	21	4	5	31	5	4	21	26	67	54
Oak Park	1st Ave	34th and 35th	12.5	6	9.5	49	9.5	6	12.5	14	33	28
East Sacramento	38th	Folsom and R	36.5	4	7.5	37/58	7.5	4	36.5	34	54	68

Fig. 1—"Typical" treescape conditions for the studied streets with planting strips. Drawing, including tree height, crown, and diameter, is to scale and represents a potential future scenario that can be compared with dimensions on existing streets



No planting strip										
			Section					Tree		
Neighborhood	Street	Between	PUE	SWK	Total street width	SWK	PUE	DBH	Height	Crown diameter
Curtis Park	7th	24th and West	25.5	4.5	33	4.5	25.5	31	86	60
Curtis Park	Castro		30.5	4.5	33	4.5	30.5	29	52	48
Curtis Park	Donner, S side		30.5	4.5	33	4.5	30.5	28	68	54
Land Park	Weller	Land Park and Govan	25.5	4.5	33	4.5	25.5	18	48	47
Land Park	Harkness	Larkin and Burnett	15.5	4.5	33	4.5	15.5	29	71	56
Land Park	Land Park	Markham and 2nd	40	5	51	5	40	32	82	64
Land Park	Perkins	Govan and Riverside	30.5	4.5	33	4.5	30.5	32	70	61
East Sacramento	51st	M and Folsom	15.5	4.5	32	4.5	15.5	20	38	36
East Sacramento	46th	J and Folsom	43.5	6.5	32	6.5	43.5	38	72	68
East Sacramento	45th	J and Folsom	45.5	4.5	41	4.5	45.5	31	69	56
East Sacramento	44th	J and Folsom	40.5	4.5	35	4.5	40.5	31	67	60
East Sacramento	40th	Folsom and R	20.5	4.5	32	4.5	20.5	32	71	50

Fig. 2—“Typical” treescape conditions for the studied streets without planting strips. Drawing, including tree height, crown, and diameter, is to scale and represents a potential future scenario that can be compared with dimensions on existing streets

species planting nor distinct eras of planting except in plats developed after World War II. The result is a mixed age, mixed species street tree population.

In the 1950s, construction of Highways 99 and 50 and associated street widening and underpass construction changed the face of the community. The era that brought freeways to Sacramento heralded the development of extensive hardscape. It seems as if air-conditioning had arrived and shade trees were deemed no longer necessary. Old tree-lined boulevards were widened, paved, and left predominantly treeless. The change to the entrance of Oak Park is visible in Fig. 3. Oak Park illustrates the concept that our communities are shaped, sometimes to their detriment, by transportation technology.

Fig. 3—The entrance to Oak Park with the original trolley system and now, at the corner of Broadway and Alhambra Boulevard

Street Tree Structure

Since there was no systematic development within Oak Park, it is not surprising that a street tree planting pattern or plan has not emerged over the past 100 years. Only in newer tracts, built upon later by developers predominantly in the southern portion of Oak Park, were trees planted along every street. From earlier eras, there are remnants of rows of date palms, a magnificent row of redwoods dwarfing small cottages set less than 10 ft back from tree centers along 1st Avenue, and the occasional giant eucalyptus – a reminder that the city once promoted them as trees for good health (McPherson and Luttinger 1998). In sampled locations, planetrees (*Platanus occidentalis* and *P. orientalis*) were predominant, representing about one-fifth of sampled trees. The Oak Park sample had more age diversity than the other park neighborhoods with a significant number of newly planted trees present.

Table 2 shows the wide array of species planted before 1940 and most are still present, although some species (like elms) are not present in the same numbers. Street segment sampling revealed 10 species planted in the early years of development, 86% of which were large and 14% medium-sized at maturity. Starting in the 1920s, the city began annual campaigns to plant street

Table 2—Oak Park species and size class representation for the original and current tree populations. Estimates obtained from sampled streets. Note increase in number of species

Trees planted by height size classes		
Size	Original (%)	Current (%)
Small (0–30’)	0.0	10.3
Medium (30–50’)	13.8	25.8
Large (50 +)	86.2	63.9
Species (*n*)	10	34
Species planted before 1940s		
Dominant:	*Ulmus campestris* - English elm, *Eucalyptus globulus* - blue gum, *Platanus occidentalis* - American planetree, *P. orientalis* - Oriental planetree, *Zelkova serrata* - sawleaf zelkova, *Quercus lobata* - valley oak, *Phoenix canariensis* - date palm, *Washingtonia* spp. - fan palm, *Sequoia sempervirens* - coast redwood	
Existing species		
Dominant:	*U. parvifolia* - Chinese elm, *P. occidentalis* - American planetree, *P. orientalis* - Oriental planetree, *Zelkova serrata* - sawleaf zelkova, *Celtis sinensis* - hackberry, *Fraxinus velutina* ‘Glabra’ - Modesto ash, *Cinnamomum camphora* - camphor tree	
Additional:	*Acer* spp. - maple species, *Sequoia sempervirens* - coast redwood, *Quercus lobata* - valley oak, *Q. suber* - cork oak, *Washingtonia* spp. - fan palm, *Phoenix canariensis* - date palm, *Pistacia chinensis* - Chinese pistache, *C. camphora* - Camphor tree	

trees in residential neighborhoods (McPherson and Luttinger 1998). In a 1938 *Western City Magazine* article, Frederick Evans, Sacramento Parks Superintendent, discussed 15 newer species being offered to city residents. All 15 of these species are currently present in Oak Park in large numbers, indicating that planting continued into the 1940s.

Over the past 20 years, many new trees and species have been planted in Oak Park through the Sacramento Tree Foundation Neighborwoods Program and Sacramento Municipal Utility District’s Shade Tree Program. Thirty-two species were present along the five sampled segments. Tree DBH ranged from 1 to 63 inches with an average of 13.4 inches, indicating the presence of many younger trees. Tree height averaged 46 ft and crown diameter 45 ft. Additionally, over 10% of the trees sampled along segments were small species and 26% were medium. Compared to early species selection, this represents a shift toward selecting smaller trees that will produce fewer benefits.

Oak Park’s relatively unplanned planting resulted in what could be a very sustainable street tree population given the species and age diversity present. However, there are both design and maintenance concerns that impact the overall sustainability of the trees by limiting life spans. These will be addressed in subsequent section.

Planting Space

In Oak Park, 49% of trees were planted in planting strips, 51% in lawns and 1% in medians (Wolfe Mason 1992). Sampled planting spaces included all three configurations (Table 3). Except in those areas with the smallest set-

Table 3—Oak Park treescape configurations. The five sampled segments generally had a mix of species, and less available space for trees but more trees planted in that space than found in other park neighborhoods

Street	Between	Typical species	Planting space	Ave. space between trees (ft)	Tree to concrete setback (ft)	Tree to building setback (ft)	Greenspace adjacent to bldg (ft)
35th St.	T and V	Mix	Lawn	24; 15–46	8.5	15	23.5
Broadway	36th and 35th	Fan palm	Median	25; 25–50	2.3	NA	0
Broadway	36th and 35th	Magnolia	Strip	30; 30–70	4	7.5	0
1st Ave.	39th and 37th	Mix	Strip	51; 16–193	4	22	11.5
X St.	32nd and 34th	Mix	Strip	29; 15–45	2	23	15.5
1st Ave .	35th and 34th	Mix	Strip	24; 11–47	5	23	12.5

backs, there were usually not consistent setbacks between the structures and the streets.

In the commercial district along Broadway, the median trees were all fan palms (*Washingtonia robusta*) planted equidistant from each curb in the 4.7-ft-wide median.

Lawn trees were set back from sidewalks 8.5 and 15 ft from homes on 35th Street in a configuration typical of lawn treescapes throughout Oak Park. This provided rooting space of 23.5 ft between building and sidewalk. Average space between trees was 24 ft, but ranged from 15 to 46 ft.

Planting strips averaged 8 ft in width, but ranged from 4.5 to 9.5 ft wide. Since sidewalk damage was prevalent everywhere, regardless of the presence or absence of trees, no clear relationship between tree roots and infrastructure damage could be determined. In most cases, it appeared that the walks were very old and concrete failure was due to age rather than tree roots.

The 9.5-ft-wide planting strips were common in the community, along with 5- to 6-ft-wide sidewalks. A typical street configuration is shown in Fig. 4, where the planetrees have adequate space to grow. The homes in many of these areas are setback as little as 11.5 ft from the sidewalks. As the photo demonstrates, this leaves little room for additional trees adjacent to the house. In areas where other trees were planted, stunting, conflicts, and irregular growth habits were noted. Figure 5 shows young mulberries in conflict with the house front and leaning toward the street. The growth of the younger trees in the planting strip is also being affected.

Table 4 indicates that there are more trees per parcel where planting strips exist. There were an average of 1.3 trees per lot planted in strips compared to 1.1 in lawns. Many trees in the strips were new compared to in lawns as is indicated by the lower average DBH of planting strip trees. Sacramento Tree Foundation staff have worked in recent years to plant more trees in the strips. Unfortunately, the mortality rate was also high therebecause the trees tend not to be watered regularly. Our estimate of replanting rates based on sampled segments shows that the majority of planting strip trees were replants (78%).

Fig. 4— A planetree planted 21.5 ft on center from this Oak Park home has adequate space to grow in a 9.5-ft strip. Note that pruning is necessary to reduce limb conflicts with the house until the tree has grown sufficiently to permit raising its crown above roofline

Fig. 5—These mulberries were planted too near the residence to allow their crowns to develop properly. Pruning to reduce conflicts with the home will result in an imbalanced crown and increase the lean already present

Infrastructure Conflicts

As previously mentioned, we were unable to clearly relate sidewalk damage to tree roots due to the prevalence of damage regardless of whether or not a tree was present. There were clearly many more conflicts with utilities in Oak Park than in any other neighborhood. It was the only one of the five neighborhoods where utilities ran predominantly along the main streets despite the existence of alleys. Significant tree crown reduction along some streets has occurred to reduce conflicts, but telephone and cable lines can be seen running in five different directions through tree crowns along some streets.

There was also a significant conflict between trees and homes and sidewalks in locations where houses are setback 12 ft or less from the sidewalks

Table 4— Average tree dimensions and presence along sampled segments in Oak Park

Location	Ave. DBH (in)	Ave. height (ft)	Ave. crown diameter (ft)	Ave. trees per lot (*n*)	Houses w/o trees per segment (*n*)	Trees re-planted (%)	Perpendicular planting space
Lawn	26	59	59	1.1	4	20.6	24
Planting strip	12	33	31	1.3	4.3	78.2	8
Median	14	72	14	8[a]	NA	Unknown	5

[a] Trees per block

and huge mature trees now exist in this space. In many cases, the entire front yard is raised several feet above road level and the level of other homes in the neighborhood. Sidewalks, walkways to front doors, and driveways are ramped over these root-created berms.

Management

Trees in Oak Park overall have suffered from a lack of management for many years. Many are in need of structural pruning and better care. This is not a surprise in an area that is slowly undergoing renewal after years of neglect. Generally, in neighborhoods where families are struggling economically, trees tend not to be pruned and often are absent entirely. Larger, older trees are relatively free of hazards, indicating that the city is probably monitoring the trees for safety.

On a brighter note, new trees being planted are receiving structural pruning through volunteer efforts and neighborhood pruning classes available from the Sacramento Tree Foundation.

Tree Issues Unique to the Neighborhood

The primary concern is large trees in spaces with too little planting space adjacent to homes, resulting in conflicts. Because lots tend to be smaller overall in Oak Park, planting large species may not be possible in areas with little or no setback. In these cases, the tree size needs to be matched to the space.

Curtis Park

Neighborhood Overview

There were several stages of development in Curtis Park, defined primarily by periods when resident farms and ranches were sold or divided for development. The original Curtis Park was bordered by Broadway and Sutterville Road to the north and south, and Freeport and Franklin Boulevards to the west, and the eastern area was home to the Odell Stockyard, Sprague Dairy, the Brockway and Edwards farms, and the Moor, "Uncle Billie" Richards, and Curtis Ranches until the 1880s. The Odell Stockyard became the first development area within Curtis Park. Renamed Highland Park, the land was divided into 275 lots and the first 59 were sold in 1887 at an average price of $164. This area underwent major reconstruction after Highways 99 and 50 were built, becoming predominantly commercial from Broadway south to 2nd Avenue.

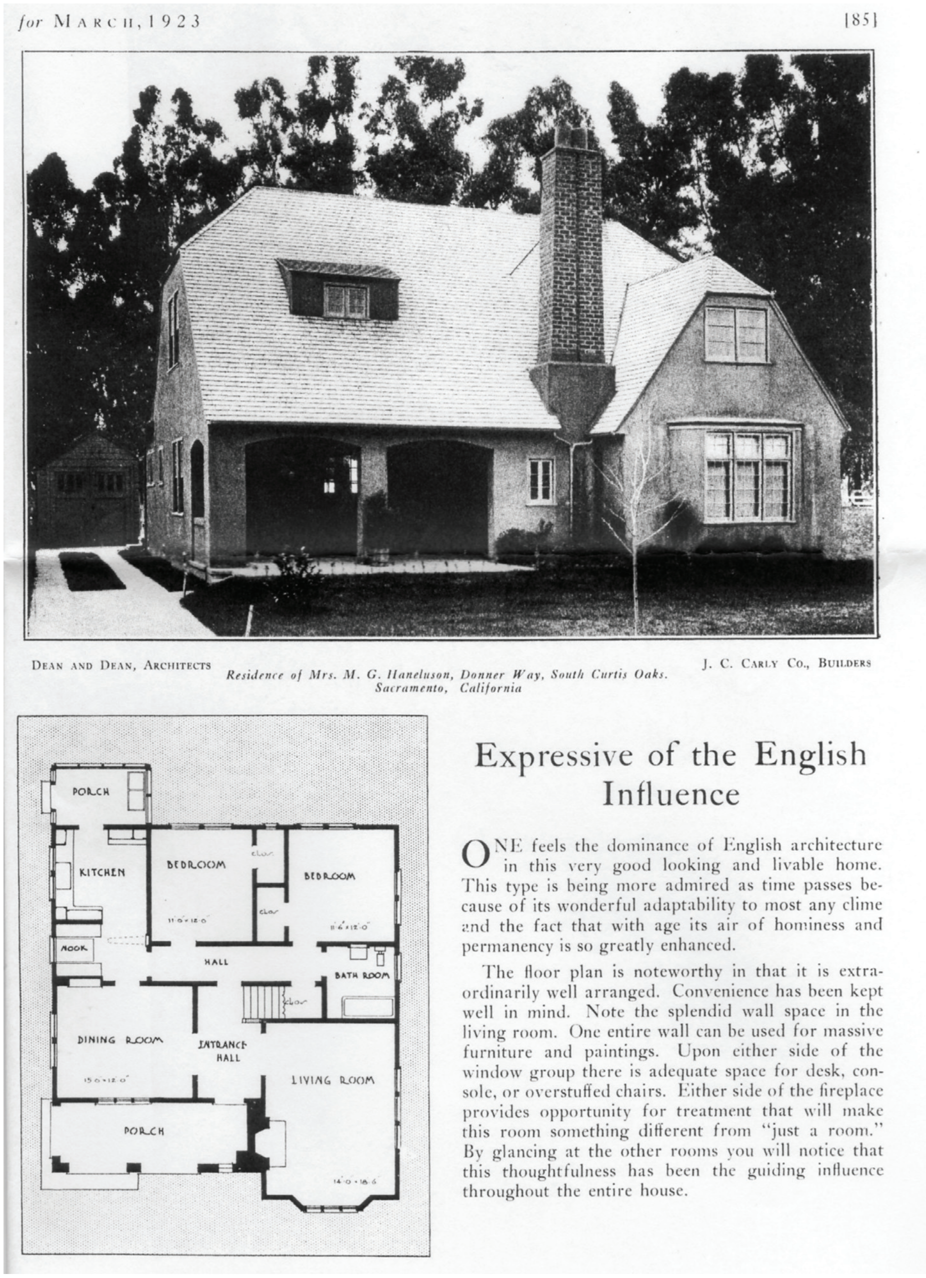
The Curtis Park boundaries delineated in the Wallace engineering report (2007) omit the section of Curtis Park north of Castro (roughly the old Sutter Grant line). We include it because it illustrates the transformation neighborhoods experience when transportation corridors change. When considering sustainable development, it also illustrates the need to consider future transportation infrastructure corridors in planning. Freeway development through Curtis Park and subsequent commercial development adjacent to the freeway removed hundreds of mature elms and planetrees lining 24th through 26th Streets. Specifically, associated benefits were lost, replacing them with a gray infrastructure that increases stormwater runoff and adds to the city's urban heat island effect, carbon production, energy usage, and poor air quality.

The land south of Castro Way in today's Curtis Park has remained predominantly residential. It was originally populated with native stands of valley oak (*Quercus lobata*), once carefully tended by the Nisenan-Maidu people, the region's first human inhabitants (Anderson 2005). The first Anglo settlers arrived in the mid-1800s, including the Curtis family and eventually added windrows of eucalyptus trees (*Eucalyptus globulus*) to their homesteads. Some of these original eucalypts still survive along Franklin Boulevard and have 5-ft diameters. The Sacramento City Council enacted an ordinance for planting eucalypts for health reasons in the last quarter of the 19th century and these Curtis Park plantings may be a result (McPherson and Luttinger 1998).

Infill of the various Curtis Oaks tracts and associated street construction and improvement caused either the removal or eventual death of the majority of the native oaks, but a few still remain like the oak growing out of the middle of 3rd Avenue's asphalt roadway. A newcomer to Montgomery Way near Franklin Boulevard would wonder why the first several hundred feet of the street is nearly 10 ft narrower than the remainder: until several years ago, stately native valley oaks bordered this narrow entrance (Fig. 6), carefully protected from removal when the street was prepared for sidewalks and gutters in the 1920s. The vestiges of eucalyptus windrows planted along the Curtis family's ranch frontage can still be viewed behind some of the houses along Donner Way (Fig. 7).

Fig. 6—The native oaks at the entrance to Montgomery Street were preserved (*top photo*) during development. *Bottom photo* shows current narrow entrance still remains although oaks were recently removed

Real estate advertisements for Curtis Park tracts (Murphy 2005) included the promise of shade: "Ornamental trees will be set out on the tract as soon as possible." In an era when street grading was done by hand or horse-drawn implements, early photos reveal that every effort was made to save existing trees. They were a vital, functional component of the landscape, nature's air-conditioners providing much-needed shade during scorching summers and wind reduction during all seasons. That said, it appears in many historic photos of homes that not


for MARCH, 1923 [85]

DEAN AND DEAN, ARCHITECTS

Residence of Mrs. M. G. Haneluson, Donner Way, South Curtis Oaks. Sacramento, California

J. C. CARLY CO., BUILDERS

Expressive of the English Influence

ONE feels the dominance of English architecture in this very good looking and livable home. This type is being more admired as time passes because of its wonderful adaptability to most any clime and the fact that with age its air of hominess and permanency is so greatly enhanced.

The floor plan is noteworthy in that it is extraordinarily well arranged. Convenience has been kept well in mind. Note the splendid wall space in the living room. One entire wall can be used for massive furniture and paintings. Upon either side of the window group there is adequate space for desk, console, or overstuffed chairs. Either side of the fireplace provides opportunity for treatment that will make this room something different from "just a room." By glancing at the other rooms you will notice that this thoughtfulness has been the guiding influence throughout the entire house.

Fig. 7—Advertisement from *Home Designer Magazine* for new homes along Donner Way. Note new planetree in front yard and eucalyptus windrow from Curtis Ranch in rear

all developers made good on the promise to plant trees. Planting beyond main transportation corridors was often dependent upon when individual streets and lots were actually developed. This explains the variation in size and species of many of the oldest trees.

Street Tree Structure

Table 5 shows that tree planting prior to the 1940s was dominated by elms (*Ulmus procera* and *U. americana*) and Oriental planetrees (*Platanus orientalis*), with accent trees including Canary Island palms (*Phoenix canariensis*) and coast redwoods (*Sequoia sempervirens*).

As in Oak Park, early development in Curtis Park did not receive the benefit of the new tree planting program begun in the 1920s by the city, but today's existing tree population shows homeowners in the late 1930s took advantage of the city's free tree program. Along with planetrees, current dominant species planted between the 1940s and 1960s include zelkova (*Zelkova serrata*), hackberry (*Celtis sinensis*), and Modesto ash (*Fraxinus velutina* 'Glabra'). Accent trees included deodar cedars (*Cedrus deodara*), particularly on corner lots, redwoods (*Sequoia sempervirens*), and date palms (*Phoenix canariensis*).

Original species planted were predominantly rapid-growing large species. Over 93% of the first trees planted that still exist are large. No original small trees were found, but small trees typically have significantly shorter life spans. The tree population that dates back to before the 1940s includes 11 species, not dissimilar to the 15-tree species selection offered by the city in the 1930s. The current population includes 29 species, with 78% being large-growing trees, 19% medium and about 3% small trees. This represents a significant shift; although more species are planted, mature tree size is smaller overall, decreasing the potential benefits.

Oak Park is still dominated by mature trees. The 1992 Sacramento Urban Forest Management Plan states that 97% of the trees were mature, 2% young and only 1% declining. Indications from the street segments sampled are that the percentage of mature trees has declined over the past 15 years, and more young trees have been planted. Average DBH for sampled segments was 26 inches, indicating the predominance of mature trees. Average height and crown diameter were 61 and 46 ft, respectively. An Oriental plane 100 ft tall and 76 in diameter is planted at the site of the home that was once the cabin for the Harkness Ranch manager on what is now Harkness Street.

Table 5—Curtis Park species and size class representation for the original and current tree populations. Estimates obtained from sampled streets

	Trees planted by height size classes	
Size	Original (%)	Current (%)
Small (0–30')	0.0	2.6
Medium (30–50')	6.9	19.1
Large (50 +)	93.1	78.3
Species (*n*)	11	29
	Species planted before 1940s	
Dominant:	*Quercus lobata* - valley oak, *Eucalyptus globulus* - blue gum, *Platanus occidentalis* - American planetree, *P. orientalis* - Oriental planetree, *Ulmus americana* - American elm, *U. procera* - English elm	
	Existing species	
Dominant:	*P. occidentalis* - American planetree, *P. orientalis* - Oriental planetree, *Zelkova serrata* - sawleaf zelkova, *Acer rubrum* - red maple, *Celtis sinensis* - hackberry, *Fraxinus velutina* 'Glabra' - Modesto ash, *Pyrus calleryana* - callery pear	
Additional:	*Cedrus* spp. - cedar species, *Pistacia chinensis* - Chinese pistache, *Sequoia sempervirens* - coast redwood, *Quercus rubra* - red oak, *Phoenix canariensis* - date palm, *Liquidambar styraciflua* - sweetgum	

Planting Space

Street tree planting configurations in Curtis Park consist of 45% planting strips, 54% tree lawns and 1% medians (Wolfe Mason 1992). Planting spaces sampled were lawns (sidewalks contiguous with the street) and planting strips (planting strip between sidewalk and curb). Normally residential streets are designed with one planting configuration along any single block and usually the entire street. This was true for sampled streets in Curtis Park with the exception of Donner Way where trees on the south side are in lawns and on the north side in 5-ft-wide planting strips (Table 6). Planetrees represent nearly 60% of all trees planted, 65% of those in lawns and 43% of those in planting strips.

Lawn trees were set back from sidewalks 7.5–9.5 ft and away from buildings 20–27 ft. (Tree setback from curb was measured from inside of the curb to tree bole center.) This provided these trees with a rooting space between sidewalks and structures of 25.5–30.5 ft (perpendicular to roadways). Generally, there was an average of 50–56 ft between trees planted along streets, but trees were dispersed anywhere from 30 to 105 ft apart as some lots did not have any trees.

Trees had significantly less space to grow in the 5-ft-wide planting strips where tree centers were only 2.5 ft from the nearest concrete. The average diameter-at-breast height (DBH) for planting strip trees here was 24 inches. Research shows that a conservative estimate of mature tree buttressing flare at the base of large trees is two to three times the diameter of the tree (Peper unpublished data). For a 24-inch diameter tree this virtually ensures that the hardscape surrounding a 5-ft diameter planting strip will need repair or replacement over the lifetime of the tree.

Table 7 indicates that street segments with planting strips tended to have more trees, averaging 1.8 trees per lot compared to 1.1 on lawns. There were also fewer missing trees (or spots for trees that were never planted or replanted). However, planting strip trees tended to have a smaller DBH, did not grow as tall and had narrower crown diameters than lawn trees. Additionally, 39% were estimated to be replacement trees compared to 21% replacement on lawns, indicating that mortality levels are higher for planting strip trees.

Table 6—Curtis Park treescape configurations. Although several sampled segments had a mix of species, planetrees were predominant overall. Lawn planting space was much larger here than in Oak Park

Street	Between	Typical species	Planting space	Ave. space between trees (ft)	Tree to concrete setback (ft)	Tree to building setback (ft)	Greenspace adjacent to bldg (ft)
7th St.	24th and West	Planetree	Lawn	56; 45–105	9.5	20	25.5
Castro Way	2600-2661	Planetree	Lawn	50; 30–100	8	27	30.5
Donner, south side	2400-2600	Mix	Lawn	38; 35–42	7.5	23	30.5
Donner, north side	2400-2600	Mix	Strip	38; 35–42	2.5	22.5	15.5
Portola	24th and 26th	Mix	Strip	33; 14–88	2.5	20	12.5

Table 7—Average tree dimensions and presence along sampled segments in Curtis Park. More trees were planted in strips than lawns, but replacement rate was higher

Location	Ave. DBH (in)	Ave. height (ft)	Ave. crown diameter (ft)	Ave trees/ lot (*n*)	Houses w/o trees per segment (*n*)	Trees replanted (%)	Perpedendicular planting space
Lawn	28	68	54	1.1	2	20.7	29
Planting strip	24	53	42	1.8	0.5	39.1	5

Infrastructure Conflicts

Few utility conflicts were noted in Curtis Park. Early in the history of the community, some utility lines ran adjacent to residential streets, but these were moved many years ago. The majority of utility lines through residential areas run behind houses or in alleys.

Seventy-eight percent of the planting strip trees were associated with sidewalk damage. Fifty-two percent had heaved the sidewalks more than 1-1/2 inches or were associated with sidewalks that had been replaced. About 56% of the lawn trees with minimum setbacks from sidewalks of 7.5 ft were associated with damage, and only 24% with sidewalk replacement or sidewalk heaves greater than 1.5 in. Note that the lawn trees were larger than the planting strip trees but caused less damage, probably due to increased setback and soil volume.

No conflicts with the residential structures were observed for trees in either planting space. Trees with large crown dimensions had grown tall enough to extend over the rooftops, but their crowns had been raised or pruned so that no hazard was posed to homes.

Management

Historic photos of early Curtis Park tree plantings show young trees with balanced crowns. Some appear to need pruning for structure, but given the current structure and condition of the oldest planetrees – their height and balance – it appears that they received necessary pruning and care as they matured. Once the neighborhoods became part of the city, the trees were managed by crews with the City of Sacramento Parks Department until a 1990 street tree maintenance moratorium was placed on the city's 57,500 street trees due to budget cutbacks (McPherson and Luttinger 1998). Tree care abruptly became the responsibility of homeowners.

The quality of care all trees receive is dependent upon the skill level of the tree trimmer or arborist homeowners hire. The majority of large Curtis Park trees appear to receive good care and pruning. However, younger trees could use better structural pruning and crown cleaning.

Based on relative age distribution on sampled streets, about 57% of the tree population is mature and/or senescent (over 24 inches DBH). Over 78% are in fair or better condition, suggesting that the care they received throughout their lives prepared them for better health in "old age."

Tree Issues Unique to the Neighborhood

As the large old trees in the community reach the end of their lives, planting new trees that will be similar in stature will be difficult along some streets without removing trees first. This is particularly true along streets where greenspace between house and sidewalk is limited to 15 ft or less. The problem is that new, young trees are shaded out by the old trees. An example of this can be seen on Harkness where a homeowner planted an Oriental plane over 10 years ago. It has grown to 28 ft tall as it tries to reach for light, but remains 4 inches in diameter and sickly.

In other areas where there is adequate space for large trees, removed trees are being replaced by homeowners with small to medium-sized trees – such as crape myrtle (*Lagerstroemia indica*) , dogwood (*Cornus* spp.), and pistache (*Pistacia chinensis*) – who are probably unknowingly shrinking the community's forest and reducing benefits for the future.

McKinley Park

Neighborhood Overview

The park that provides the name for this community was originally part of the historic Burns Slough, which left the American River at the current site of California State University, Sacramento, and flowed west and south through midtown to what was a wetland area and is now Land Park. As the city developed, the slough was diverted farther and farther east using a variety of means. Eventually the slough was routed down Alhambra Boulevard where it was finally placed underground through a huge drain and sewer system. McKinley Park's pond is the remnant of the original slough, although many times rebuilt. In its early stages, McKinley Park (then East Park) was owned by the Sacramento Electric Railway Company. Their initial development of the park as a private enterprise included planting willows along the slough.

The city's eventual purchase of the land in 1902 was not highly regarded because much of McKinley was still swamp-like. One of Sacramento's wealthy patrons, Mrs. J. Henry Miller, took on the task of turning the swampy park into a garden, designing and organizing tree plantings. She was soundly ridiculed at the time, but honored later in 1938 when the beautiful results of her work were much enjoyed by citizens. Ironically, when Sacramento finally recognized her contributions she was living in near-poverty in a tiny apartment off of J Street as her family had lost everything during the stock-market crash (Sacramento Union 1936).

Although development around the park was piecemeal, the predominant species planted along H Street, McKinley Boulevard and residential streets surrounding the park were again planetrees – both Oriental and American. English elms were also planted but few remain today. North of McKinley Park, D Street was among the first developed and has the largest remaining planting strip designed in early Sacramento history – 15 ft. The majority of the homes in this area were built after 1911, and a concrete stamp shows that sidewalks were installed in 1914 by the Clark & Henery Construction Company. The planetrees on D Street represent some of the oldest and largest planted in the McKinley Park neighborhood (Fig. 8). Although the homes are setback from the sidewalks only 19 ft, the road width coupled with a 15-ft planting strip and 6-ft sidewalk creates a sense of spaciousness along the street and provides the large tree crowns with adequate space.

In direct contrast, 37th Street lacks this spacious feel. Home building began in the 1920s along this street. The street itself is only a couple of feet narrower than D Street, but planting strips are only 5 ft and sidewalks 4 ft. Most houses are set back from the sidewalks 21 ft. In comparison to the studied area of D Street, 37th Street has a much different, somewhat crowded feeling.

Original species throughout McKinley were predominantly large species, including planetrees, Modesto ash, and elms with accent species including redwoods, sweetgum (*Liquidambar styraciflua*) and ginkgo (*Ginkgo biloba*) (Table 8). Current species include all of these plus zelkova, deodar cedar, magnolias, and Chinese pistache. McKinley is the smallest of the sampled neighborhoods and has the least species diversity.

The trees are predominantly mature with few new plantings. Average DBH across all planting configurations was 28 inches, with average height and crown at 76 and 56 ft, respectively. Trees crowns tend to be wider than lot widths and also arch and meet over the streets.

Fig. 8— Majestic planetrees thrive in the 15-ft planting strip on McKinley Park's D St. One of the city's largest ginkgos is also planted here

Planting Space

Much of McKinley Park's planting space is in lawns rather than planting strips but the neighborhood provided an opportunity to examine similarly-aged trees of one species– mature planetrees planted 70–95 years ago – in two different planting strip configurations of 5 and 15 ft widths.

Table 9 shows only a 5-ft difference between tree center and building setbacks for both streets. Tree crown diameters (Table 10) are similar and do not conflict with buildings. In neither case are additional medium or large-sized trees planted in the greenspace adjacent to the homes that might compete for growing space. However, the trees in the smaller planting strip have smaller DBHs and are nearly 20 ft shorter on average. This was a typical observation throughout small planting strips in McKinley Park. Even more significant is the 26% replanting rate for the 5-ft planting strip compared to 6% in the 15-ft strip. There are slightly more trees per lot along the smaller planting strip, but this was due to new plantings placed closer together (as close as 21 ft). Concrete replacement was much more common in the narrow strip and included special mitigation techniques like meandering the sidewalks around basal flares and removing curbs to provide more room and reduce future damage. There was also evidence that roots had been cut more than once when sidewalks were replaced and this likely inhibited tree growth (see Fig. 9).

Over 44% of the planes in the wider planting strip were in good condition compared to only 17% in the 5-ft strips. This indicates higher potential for tree mortality for the smaller strip.

Table 8— McKinley Park species and size class representation for the original and current tree populations

Trees planted by height size classes		
Size	Original (%)	Current (%)
Small (0–30’)	0.0	2.4
Medium (30–50’)	2.8	7.2
Large (50 +)	97.2	90.4
Species (*n*)	4	12
Species planted before 1940s		
Dominant:	*Platanus occidentalis* - American planetree, *P. orientalis* - Oriental planetree, *Fraxinus velutina* ‘Glabra’ - Modesto ash, *Ulmus* spp. - elms	
Existing species		
Dominant:	*P. occidentalis* - American planetree, *P. orientalis* - Oriental planetree, *Zelkova serrata* - sawleaf zelkova, *Fraxinus velutina* ‘Glabra’ - Modesto ash, *Cedrus deodara* - deodar cedar	
Additional:	*Pistacia chinensis* - Chinese pistache, *Magnolia grandiflora* - Southern magnolia, *Liquidambar styraciflua* - sweetgum, *Ulmus parvifolia* - Chinese elm, *Ginkgo biloba* - ginkgo	

Table 9—Treescape configurations in McKinley Park. Note that the narrower planting strip has more trees

Street	Between	Typical species	Planting space	Space between trees (ft)	Tree to concrete setback (ft)	Tree to building setback (ft)	Greenspace adjacent to bldg (ft)
D St.	33rd and Alhambra	Planetree	Strip	40; 36-63	7.5	32.5	19
37th St.	H and F	Planetree	Strip	25; 21-75	2.5	27.5	21

Table 10— Average tree dimensions and presence along sampled segments in McKinley Park. In narrow strips, the trees appeared stunted and were replaced at higher rate

Location	Ave. DBH (in)	Ave. height (ft)	Ave. crown diameter (ft)	Ave. trees/lot (*n*)	Houses w/o trees per segment (*n*)	Trees replanted (%)	Perpendicular planting space (ft)
Planting strip, D St.	30	85	57.5	1.1	2	5.8	15
Planting strip, 37th St.	26	67	54	1.3	3	25.8	5

Infrastructure Conflicts

There was little sidewalk, curb or gutter conflict found associated with the 15-ft-wide planting strips but significant conflict as discussed previously with the narrower strips. Utility lines run predominantly through backyards and alleys and were not present on most streets. Most of the trees have reached heights where tree crowns have been raised above signs and lights, and no conflicts were noted in these areas.

Management

Historic photos show trees with balanced crowns when young. Later photos of maturing trees along H Street, Alhambra and McKinley Boulevard show that crowns had been raised for vehicular traffic. In general they are well-shaped trees. Existing pruning calluses on many of the old planetrees are remarkable in that they are not typical calluses; the bark covering them is no different in structure than that on the rest of the tree bole – smooth and unscarred, suggestive of excellent pruning technique.

Trees in this neighborhood have been subjected to the same management cutbacks affecting all city street trees, but these trees are better cared for than those in Oak Park and in much of Curtis Park. This may be related to the higher income levels of residents. During our data collection, residents were clearly concerned about the health of their trees and obviously have the trees pruned fairly regularly to remove dead wood. The trees were often cited as one of the reasons people bought homes in the area.

Fig. 9—Curbs were cut to provide more room for planetrees in this 5-ft planting strip. All sidewalks had been replaced due to root damage

Tree Issues Unique to the Neighborhood

The predominance of mature, even-aged planetrees is the primary issue facing McKinley Park. It is vital that the city and residents work to maintain these trees as long as possible. Equally important is the need for a management plan that addresses replacement planting. As tree mortality increases due to old age, the face of the community will change drastically if replacement is not planned.

East Sacramento

Neighborhood Overview

East Sacramento is the largest neighborhood included in this study. Excluding McKinley Park in the northwest corner, it is roughly bordered by Highway 99 to the south, Alhambra Boulevard to the west, the Pacific Railroad tracks and Elvas Avenue to the north, and 56th Street to the east. From the early stages of development it has crossed socio-economic strata, extending from the more exclusive Fabulous Forties homes to the more modest blue-collar neighborhoods east of Dolores Way. Although early development began around 1910, it remained haphazard through the 1950s. Photos from 1948 show little construction beyond the installation of roads and sidewalks along Elvas Avenue north of J Street (Fig. 10).

Sacramentans were well aware of the threat of flooding along the Sacramento and American Rivers. Areas along Elvas and throughout River Park flooded regularly despite levee and floodgate systems until Folsom Dam was built in 1955. During floods, residents from outlying areas east of town could drive to Howe Avenue on Folsom Boulevard and Fulton Avenue on Fair Oaks Boulevard. It was not unusual to find cars and families gathered in the 1940s and early 50s near Fair Oaks and Fulton to peer down Fair Oaks toward the H Street Bridge to determine whether waters had receded enough to get downtown to work (Fig. 11). The dam's completion enabled the remainder of East Sacramento to join in on the post–World War II building boom.

Fig. 10—This 1948 photo taken along Elvas Avenue near CSUS shows little development and native oaks no longer present

The slower build-out of the neighborhood is reflected in both species and age diversity. Areas closer to downtown are predominantly populated with planetrees. Some streets, like 38th between Folsom and J have elms that survived Dutch elm disease. Residential streets closer to CSUS are populated with species provided by the city after World War II – Modesto ash, hackberry, zelkova, fruitless mulberry (*Morus alba*) and Chinese elm. Current dominant species include the planetrees, zelkova, hackberry, Modesto ash, sweetgum, and camphor. Replacement and new trees include Chinese pistache, Japanese maple (*Acer japonicum*), and red maple (*Acer rubrum*).

In areas developed before the 1940s, there are around 16 species commonly still present. Throughout the entire area there are at least 35 species currently along city rights-of-way. As in other areas of the city, replacements and new plantings include more small and medium-sized species (Table 11).

Fig. 11—Flooding along Fair Oaks Boulevard looking toward H Street Bridge. Hop fields lined the road where Campus Commons exists today

Modesto ash became a predominant species throughout Sacramento after World War II and has been noted in all the streetcar suburbs. The majority observed in this study are in poor condition, suffering from extensive mistletoe infestation, annual anthracnose infection, poor pruning techniques, and major structural defects. The 1992 Urban Forest Management Plan lists it as the most prevalent tree in Sacramento, with planes coming in second. Current indications in East Sacramento are that this may no longer be the case. Mortality levels are high for this species. Many have been removed and replaced with smaller species or nothing at all. The planes appear to out-survive the ash, although they also suffer from anthracnose as well as powdery mildew.

Planting Space

The 1992 Sacramento Urban Forest Management Plan estimates that 89% of city street tree planting space is in tree lawns, 10% in planting strips and 1% in medians. Residential home setbacks from curbs range from 11 to 40 ft and beyond. We examined six street segments including five with lawn planting spaces and one with a planting strip. Tree to building setbacks ranged from 15 to 45 ft and tree to curb setback from 5 to 6.5 ft for lawn planting areas. The planting strip was 7.5 ft wide with trees planted slightly off center at 3.5 ft from nearest concrete (Table 12).

Space availability in tree lawns varied widely, from 15 ft between sidewalk and structure along 51st Street to 45.5 ft on 44th Street in the Fab Forties. Along 51st there were fewer trees per lot and more lots without trees as indicated by tree spacing of 14 to 129 ft. Trees on 44th Street were spaced fairly consistently every 50 ft and were predominantly planetrees. Average DBH and height on 51st Street were 20 inches and 38 ft compared to 31 inches and 67 ft for trees on 44th Street (Table 13). The size differences reflect differences in

Table 11— East Sacramento species and size class representation for the original and current tree populations

Trees planted by height size classes		
Size	Original (%)	Current (%)
Small (0–30’)	0.4	3.7
Medium (30–50’)	4.8	13.1
Large (50 +)	94.8	83.2
Species (*n*)	16	35
Species planted before 1940s		
Dominant:	*Platanus occidentalis* - American planetree, *P. orientalis* - Oriental planetree, *Fraxinus velutina* ‘Glabra’ - Modesto ash, *Ulmus* spp. - elms	
Existing species		
Dominant:	*P. occidentalis* - American planetree, *P. orientalis* - Oriental planetree, *Zelkova serrata* - sawleaf zelkova, *Celtis sinensis* - hackberry, *Fraxinus velutina* ‘Glabra’ - Modesto ash, *Liquidambar styraciflua* - sweetgum, *Cinnamomum camphora* - camphor tree	
Additional:	*Cedrus deodara* - deodar cedar, *Pistacia chinensis* - Chinese pistache, *Magnolia grandiflora* - Southern magnolia, *Acer japonicum* - Japanese maple, *Liriodendron tulipifera* - tulip tree, *A. rubrum* - red maple	

species selection as well as planting space limitations. Trees on 51st Street also had utility lines to contend with and received utility line pruning (Figs. 12 and 13).

As in other neighborhoods, trees were planted closer together in planting strips compared to tree lawns. The elms on 38th Street averaged 39 ft between centers, but distances ranged up to 60 ft due to removals. Along 51st Street where lot widths were smaller, spacing averaged 52 ft due to removals. Space between trees in the Fab Forties averaged about 50 ft overall with maximum distance of 77 ft.

Along 46th Street it appears that the original planting approach was two-tiered. Currently some homes have street trees and an additional large tree or two (if columnar in shape) closer to the house. The largest and oldest trees in this second tier are deodar cedars. At homes where cedars exist in this second tier, there are no planetrees streetside. Conversely, where huge planetrees exist, there are no cedars. It appears that the street trees were removed over time to make room for huge tree crowns. The street also has a narrow 2-ft grass strip between sidewalk and street where no trees are planted. Originally this was probably a shrub strip, popular downtown in earlier days until a higher crime rate was associated with the strips. Shrubs often blocked views of sidewalks.

The streets throughout the Forties maintain much of their majesty because of the trees, and residents maintain them well.

Table 12—East Sacramento treescape configurations. Tree to building setbacks and greenspace available to trees varied greatly throughout East Sacramento

Street	Between	Typical species	Planting space	Avg space between trees (ft)	Tree to concrete setback (ft)	Tree to building setback (ft)	Greenspace adjacent to bldg (ft)
46th	J and Folsom	1st row: Planetree/ camphor	Lawn	48; 20–77	5.5	38	43.5
46th	J and Folsom	2nd row: Deodar cedar/redwood	Lawn	Intermittent	NA	NA	43.5
45th	J and Folsom	Planetree	Lawn	50	5.5	45	45.5
44th	J and Folsom	Planetree	Lawn	50	6.5	34	40.5
40th	Folsom and R	Planetree	Lawn	49;26–71	6.5	13	20.5
51st	M and Folsom	Elm/Modesto ash/ mulberry/planetree	Lawn	52; 14–129	5	15	15
38th	Folsom and R	Elm	Strip	39; 22–60	3.5	44.5	36.5

Table 13— Average tree dimensions and presence along sampled segments in East Sacramento. Planting strip and lawn trees averaged one per lot, but strips had more replacement planting

Location	Ave. DBH (in)	Ave. height (ft)	Ave. crown diameter (ft)	Ave. trees/lot (*n*)	Houses w/o trees per segment (*n*)	Trees replanted (%)	Perpendicular planting space (ft)
Lawn	30	67	54	1	5	21	39
Planting strip	30	51	55	1	5	48	8

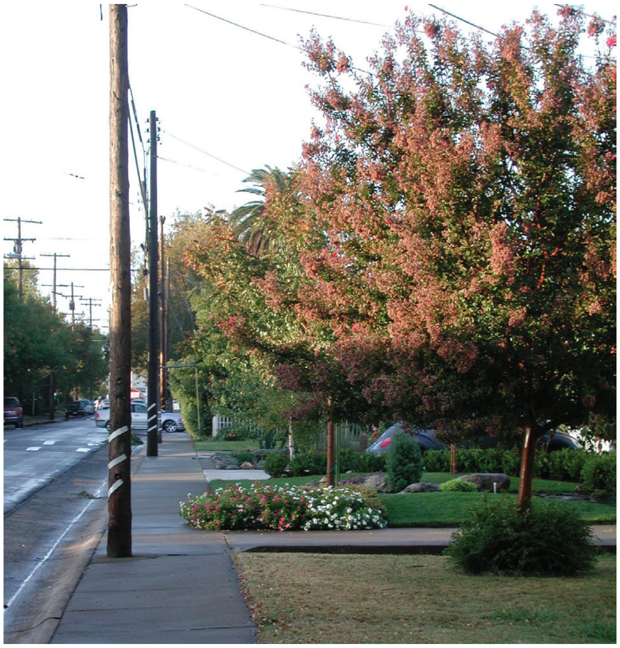


Fig. 12—Small trees are replacing medium and large trees along 51st St in East Sacramento. Utility lines are present on both sides of the street

Infrastructure Conflicts

Tree conflicts with utility lines are an issue in residential areas east of 49th Street, but not in lower-numbered streets where utilities run predominantly behind houses or through alleys. Where present, the utility lines have affected tree structure and health due to required and repeated line clearance.

Although homes along streets in the Forties area have over 40 ft of greenspace adjacent to the house fronts, the largest setback found between sidewalk and tree center was 6.5 ft. For the large planetrees this placed buttressing roots within 2 ft or less of sidewalks and damage has occurred. Where space was available it would have been wiser to plant further back on the lots, although that would have placed trees beyond the city's 12.5-ft easement. Sidewalk damage was still not nearly as extensive as that in the 7.5-ft planting strip on 38th Street.

Fig. 13—Planetrees on 44th St. had no utility conflicts and significantly more room for growth compared to trees on 51st Street

Management

Early tree management was much the same in East Park as for the rest of the city. Pruning and treatment for disease were regular until after the 1960s when budgets began to wane at the same time that tree numbers swelled.

Severe windstorms in 1941 and 1950 led the Parks Department to determine that early tree plantings were spaced too closely together (McPherson and Luttinger 1998). Among the trees removed were many in the Fab Forties, providing more space for remaining trees. This period also influenced the increased planting of smaller species in East Sacramento. Parks Superintendent William Carroll provided three examples of trees – pistache, zelkova, Modesto ash – that were thought to be storm- and disease-resistant, providing people with needed shade and fewer troubles (McPherson and Luttinger 1998). We now know that Modesto ash did not live up to those disease-resistant expectations and that their productive lives are shorter than those of planetrees and several elm species.

Now that homeowners and businesses are responsible for maintaining the street trees, the quality of care street trees receive ranges from none to extensive. Generally speaking, trees along streets numbered above 50 have suffered the most neglect (particularly ash trees), while those in the 30s and 40s receive more consistent care. The latter also tend to be longer-lived planetrees in very hospitable planting sites.

Tree Issues Unique to the Neighborhood

As in McKinley Park, continued care of the old planetrees is necessary to maintain benefits over time. In addition, citizens should be informed about the benefits trees provide and the reduction in benefits when smaller street trees are planted, particularly where there is more than adequate space for large trees. Areas west of 48th Street and north of H Street have an increasing amount of available planting space as ash are removed, and homeowners in these areas should be encouraged to replant through community tree programs, particularly since ash mortality will increase in the coming years.

Land Park

Street Tree Structure

Development in Land Park occurred from 1910 through the 1940s. Historically the area was a wetland created by seasonal flooding of the American River. Once the protests over the City's purchase of "swamp land" were overcome, Frederick Evans was hired to design the 263-acre park central to the community. Evans's design was in the Olmsted tradition and included open greenswards, trails for pedestrians and equestrians, and a golf course (McPherson and Luttinger 1998).

By 1927 the city had hired Bartholomew and Associates, a St. Louis landscape design and city planning group, to design a trolley and pleasure-drive system between parks within the city (Fig. 14). While the street component of the design was not fully implemented, their recommendations for the setback of residences from sidewalks are reflected in the similar arrangement of houses throughout Land Park (Harland Bartholomew and Associates 1927). With no air conditioning available in autos or streetcars, tree-lined boulevards were vital and tree planting along Land Park's major entrance roads occurred soon after the grading and sidewalk construction were completed. Land Park Boulevard bisects the community and is lined with the original Oriental and American planetrees, as are other primary boulevards surrounding and bisecting the park.

Planetrees and elms were the early dominant species, with redwood and cedar species providing accents along some blocks. Redwoods are clearly noticeable in a 1930s aerial view of the College Tract. Conifers served as excellent windbreaks in the flat, open former wetland (Fig. 15).

Development in the 1930s and later brought similar additions to the planting palette as elsewhere in the city. Platanus and ash predominated, but zelkova, sweetgum, and Chinese elm were present in growing numbers. We found 30 species present along the five street segments sampled. Compared to

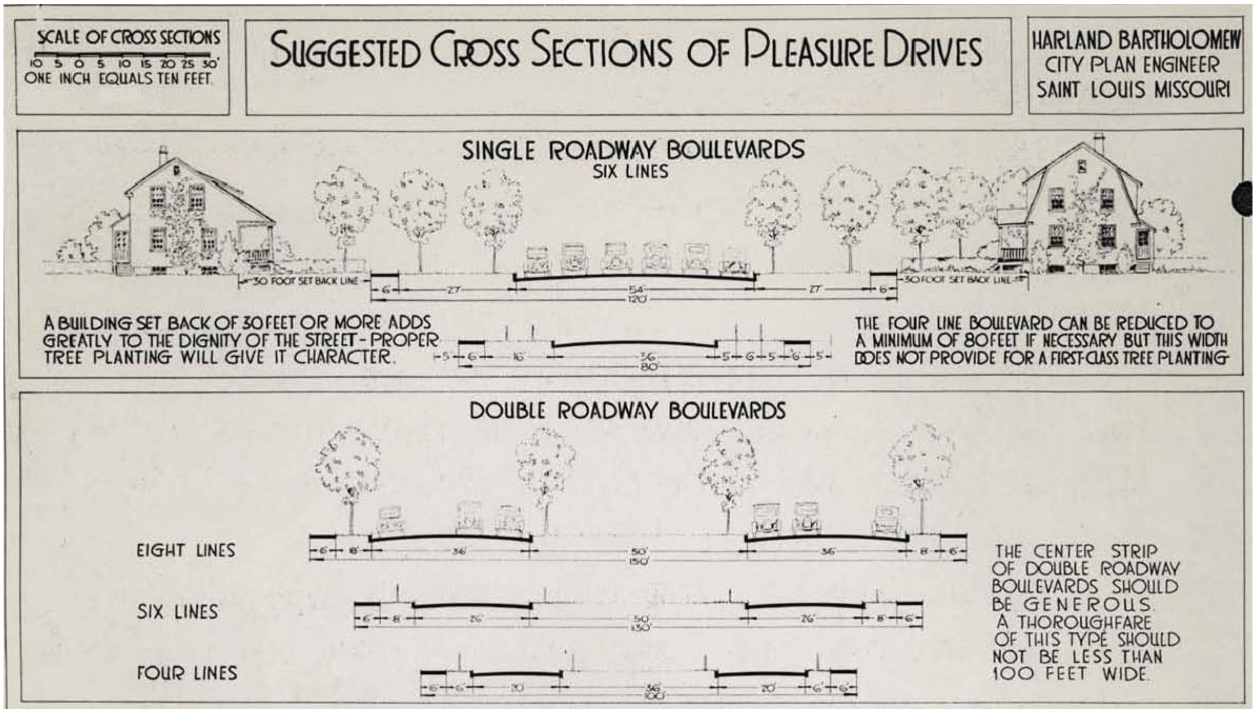


Fig. 14—A 1927 boulevard design by Bartholomew and Associates for "pleasure drives" joining Sacramento parks (Harland Bartholomew and Associates 1927)

the original species planted, there were significantly more medium and small species, including crape myrtles, planted where planetrees once grew. Based on existing trees we estimate that at least 86% of the original population was large-growing and 14% medium-growing. Today, about 26% of the trees will reach medium stature and over 10% will be small at maturity (Table 14).

Fig. 15—A 1930s' aerial view of the College Tract in Land Park. Small redwood trees can be seen along several streets

Contrary to popular belief, not all streets in Land Park were lined with trees as they were developed. With Evans as Park Superintendent, homeowners in the late 1930s were able to request trees if desired and some clearly chose to go without trees. One homeowner we spoke with said she had lived downtown originally and suffered the consequences of living under large trees during storms. When moving to Land Park in 1938 after hundreds of trees were uprooted during a single storm, she decided to never have street trees again (Weller resident 2007). Another resident who moved to a new home in 1938 stated that she remembered trees along all major north-south corridors and through the park, but that the presence of trees in many residential neighborhoods hinged upon homeowner requests to the city (Govan resident 2007).

We noted fewer trees on the south and west sides of smaller residential streets like Harkness where huge planes predominate. Clearly these homes receive much morning shade from their neighbors' trees and perhaps enough so to feel additional trees would further block morning light and sun.

Average tree DBH across all sampled segments was 25 inches. Average height and crown diameter were 64 and 49 ft. However, the old planes along Land Park Boulevard averaged 33 inches DBH and ranged up to 48 inches. Their heights extended to 122 ft, averaging 87 ft, with crown diameters averaging 67 ft. These and the planes in the Fab Forties are among Sacramento's largest street trees.

Trees in planting strips appeared to have a higher mortality rate than the lawn trees in Land Park since only 56% of the trees dated back to original planting compared to 66% of the lawn trees. Over 94% of lawn trees are in fair or better condition compared to 79% of the strip trees.

Planting Space

Setback distance between tree centers and concrete ranges from 4.5 to 10 ft and between tree center and structure from 11 to 33 ft. The least amount of space available to trees is in tree lawns on Harkness where trees are planted in a 15.5-ft space between house and sidewalk (Table 15). The combination of small lot widths and

Table 14—Land Park species and size class representation for the original and current tree populations

Trees planted by height size classes		
Size	Original (%)	Current (%)
Small (0–30')	0.0	10.3
Medium (30–50')	13.8	25.8
Large (50 +)	86.2	63.9
Species (*n*)	14	30
Species planted before 1940s		
Dominant:	*Platanus occidentalis* - American planetree, *P. orientalis* - Oriental planetree, *Ulmus* spp. - elms	
Existing species		
Dominant:	*P. occidentalis* - American planetree, *P. orientalis* - Oriental planetree, *Zelkova serrata* - sawleaf zelkova, *Fraxinus velutina* 'Glabra' - Modesto ash, *Liquidambar styraciflua* - sweetgum, *Acer rubrum* - red maple	
Additional:	*Cedrus deodara* - deodar cedar, *Pistacia chinensis* - Chinese pistache, *Magnolia grandiflora* - Southern magnolia, *Liquidambar styraciflua* - sweetgum, *Lagerstroemia indica* - crape myrtle, *Phoenix canariensis* - date palm, *Ulmus parvifolia* - Chinese elm	

setbacks with shading from the old trees makes replacement planting a challenge; new, young trees must be shade-loving varieties or they will not have strong form and structure. This means that replacement trees are likely to be understory varieties that will never reach the size nor produce the benefits now enjoyed by the community.

Average tree spacing does not differ significantly between lawn and strip trees (Table 15) with the exception of lawn trees on Perkins where average planting space is 55 ft, exceeding other street segments by 10 or more ft. The primary reason for the difference in spacing is species-driven. These trees were mostly zelkova and Chinese elm, with crown diameters wider than crown heights, whereas other streets had planes, which are taller but narrower. The trees on Perkins were planted one per lot and the older tree crowns commonly spread across the entire lot.

Trees sampled along 5th Street were a study in contrasts. All are planted in 9-ft strips, but north side trees are large, mature zelkova and planes (Fig. 16) while south side trees have been replaced with smaller species – crape myrtle, dogwood, columnar red maple, and sweetgum. The larger trees have been root-pruned multiple times during sidewalk replacement, and buttressing flares extend the width of the strip for many trees.

The average DBH and crown diameters were again smaller for trees in planting strips compared to lawn trees (Table 16). For areas with trees planted in lawns, there were, on average, eight houses without trees per segment, but there was still an average of one tree per lot overall due to the planting of multiple trees on single lots. Many new trees are being planted at 20- to 26-ft intervals.

Infrastructure Conflicts

The tree crowns of Land Park's mature trees typically extend over house rooftops as well as the roadways. There were no conflicts observed between crowns and structures, but it is obvious that careful and systematic crown raising occurred as the trees matured.

Street segments where sidewalk-to-tree-center setbacks were 4.5 ft suffered significant concrete damage, regardless of planting location type. Utili-

Table 15—Treescape configurations for Land Park

Street	Between	Typical species	Planting space	Ave. space between trees (ft)	Tree to concrete setback (ft)	Tree to building setback (ft)	Greenspace adjacent to bldg (ft)
Weller	Land Park and Govan	Magnolia	Lawn	40:26–60	5.5	20	25.5
Harkness	Larkin and Burnett	Planetree	Lawn	45; 20–75	4.5	11	15.5
Land Park	Markham and 2nd	Planetree	Lawn	45; 21–114	10	30	40
Perkins	Govan and Riverside	Mix	Lawn	55; 47–68	8.5	22	30.5
5th	17th and 19th	Planetree/ sweetgum	Strip	42; 29–68	4.5	33	24.5

ties were generally in alley ways or backyards, and few conflicts were observed between street trees, utilities, lights, or signs.

Fig. 16—The small-stature trees on the south side of 5th St. will never provide the amount of environmental benefits the zelkova and planes on the north side currently provide

Management

Management trends follow those of the other neighborhoods. City arborists respond to calls for tree assessments on a first-come first-served basis, but homeowners have been responsible for pruning and care over the past 20 years.

Generally this care is adequate, but certain species are suffering from improper pruning. One example is the Chinese elm, which often suffers from lion's-tail pruning to show off limb structure. Stress seams or fractures were visible on multiple trees, probably due to improper pruning placing too much weight at the ends of branches.

The number of new, small species being planted in spaces adequate for larger trees is indicative of the need for an overall management plan and community education about tree benefits.

Tree Issues Unique to the Neighborhood

The primary concern in this neighborhood is the introduction of more medium and small species replacing large trees as they are removed. The neighborhood clearly prides itself on the presence of tree-lined, heavily shaded streets, and if a planting plan is not developed, streets will lose this appeal.

Commercial Districts in the Park Neighborhoods

We drove through the commercial districts in all of the park neighborhoods and found the issues to be very similar to those in the one commercial area sampled in Oak Park. These districts typically run along major thoroughfares that have changed immensely since they were initially designed as tree-lined streets enticing visitors to Sacramento during hot summers.

Table 16— Average tree dimensions and presence along sampled segments in Land Park

Location	Ave. DBH (in)	Ave. height (ft)	Ave. crown diameter (ft)	Ave. trees per lot (*n*)	Houses w/o trees per segment (*n*)	Trees replanted (%)	Perpendicular planting space (ft)
Lawn	30	60	51	1	8	34	28
Planting strip	25	69	49	1	0	44	9

All of the streets have been widened (sometimes to five lanes) or rebuilt to accommodate cars, busses and trucks. Streetcar rails still exist on some but go unused. Utility lines run along many. Sewer systems, flood control systems and other wet and dry utilities run beneath the streets. Sidewalks have been laid, repaired, and widened. Trees were severely impacted by these changes and completely eliminated along some stretches (Fig. 17). Over the past 20 years the city, business community, and the Sacramento Tree Foundation have worked to replant trees in some of these areas. Additionally, some Sacramento business associations are pooling funds to retrofit and "re-green" streets dominated by hardscape, realizing that greenscapes attract customers.

The issue that stands out is the need to think systematically about relationships between green and gray infrastructure. In the recommendations and resource sections of this document we will provide resources for doing this.

Fig. 17—Intersection of 37th and J St. in 1929 (*top*) and today (*bottom*). Planting strips were paved over. A few small 4-ft square cutouts remain where trees grow

Discussion

Streets lined with large, old trees are the hallmark of Sacramento's historic park neighborhoods. Residents clearly associate the success of their neighborhoods with the presence of these trees. Many cite the trees as a primary reason for buying into the neighborhoods, despite being required to pay for pruning of huge Oriental planes and deodar cedars to qualify for homeowner's insurance. They like streets lined with large trees whose crowns touch adjacent trees and arch gracefully across boulevards. In these neighborhoods such trees were limited predominantly to planes, elms, zelkova, camphor, and valley oaks, trees with both the structure and size to allow crown raising for traffic clearance over streets.

The surveyed streets represent favored streets for home ownership within each community. Even during the current downswing in the real estate market in California, these houses have lost little, if any, value and those that go up for sale remain on the market a relatively short time. If the goal is to recreate these neighborhoods, we can learn from the problems encountered as they evolved. Early photos show homes with little or no vegetation. It took decades for trees and shrubs to grow into the lush landscape currently sheltering homes and avenues. This study provided several important insights into what worked and what didn't work in the evolution of the park neighborhoods' greenscapes. New neighborhoods should be designed with consideration not only for the aesthetic beauty trees provide, but also with their functional capacity and sustainability in mind.

The findings of this study reveal several key problem areas that impact both the sustainability and functional capacity of the street trees. These are:

- Lack of species or age diversity along streets (or both)
- Inadequate space for optimum tree growth
- Lack of a long-term urban forest management plan

Species Diversity Considerations

The 24 sampled street segments in this study, roughly equivalent to 48 linear city blocks, held surprising species diversity – 59 tree species ranging in age from newly planted red maples to several remaining native valley oaks in Curtis Park, likely several hundred years old.

Although 59 species are currently present along study street segments, nearly 52% of the trees are planetrees. This far exceeds the general rule that no single species should represent more than 10% of the population and no genus more than 20%. Although these segments cannot be used to estimate the entire street tree population, planetrees are currently the most commonly planted large tree in new developments in the Sacramento region because they are clearly a long-lived, successful species. The dominance of any one species puts that population at risk.

One need only review the removal in 1 year of 30,000 elms in Minneapolis, MN, the infestation and destruction of nearly every larch tree for miles around Anchorage, AK, and the current Asian longhorn beetle quarantine of maples and related species in New York City to realize that too much of any one tree can result in massive canopy and benefit loss.

Trees in Sacramento's older neighborhoods will probably die natural deaths of old age. The problem is that so many of the trees are the same age along entire streets. The effect of the majority of the trees all dying within a 10- to 20-year period will change the face of the neighborhoods and leave residents without the ecosystem services that trees provide until new ones can grow up again.

Tree selection at the planting site and regional scale is critical to the future sustainability of Sacramento's urban forest. Our study of the park neighborhoods provides additional information on which species are best suited to the Sacramento region. At the regional scale, these species should be the emphasis for future plantings. This will be discussed at greater length in the second part of this report. At the regional scale most plantings should consist of species proven to be well-adapted to local conditions plus a small percentage of untested trees that merit evaluation. Fortunately, Sacramento has a climate conducive to many species and there are proven species beyond planes that can be planted. The Appendix lists some of these, including trees recently selected by the Sacramento Tree Foundation's Tree Advisory Committee for small to large planting spaces.

At the planting site scale, it is important to select species and cultivars that best match requirements of the site. In several of the park neighborhoods recent selections are poor. Planting crape myrtle and dogwood, for example, in lawns or 9-ft planting strips is not the best utilization of space. Recommendations for making the most use of limited space are also discussed below.

Planting Space for Optimum Tree Growth

Table 17 shows several interesting relationships across the park neighborhoods. Note that where there is less planting space (typically in planting strips) there are more trees planted, but also more have been replaced. The exception is Oak Park. Recent replacement planting along strips there has trees placed as close as 11 ft apart. The assumption may be that mortality levels will remain high as they have in the past, so it is okay to over-plant strips. Except for Oak Park, the pattern emerging from this study is that more space equals larger trees with longer lives. There are also indications that a 15 ft planting strip is essentially equal to a tree lawn and trees here will also grow larger and live longer.

Table 17 also shows overall planting area for trees (parallel space × perpendicular space). The trend is that as planting area increases, so do tree spacing, tree height, and in some cases (dependent upon predominant species type) tree crowns. The trees have space to grow. They are not stunted by extensive competition for soil volume.

The distance trees are set back from concrete can affect tree health, growth, and mortality. Figure 18 shows the relationship between incidence of concrete upheaval and/or replacement due to tree roots and the distance the trees are planted from concrete. This graph represents the large trees sampled, those over 24 in DBH. Nearly 86% of all trees in strips less than 4 ft wide significantly damaged the nearby hardscape. One-third of the trees with centers 8 ft from the concrete caused damage. At the soil line, the root flares of these trees were 4 ft from the curb or concrete.

Note the lack of damage when tree centers were 10–12 ft from concrete. Of course, extent of damage is dependent upon many factors including soil

Table 17—Comparison of trees in the two major planting space types – lawns and planting strips

Neighborhood	Location	Total planting area (ft^2)	Perp. planting space (ft)	Ave. (range) DBH (in)	Ave. (range) height (ft)	Ave. (range) crown diameter (ft)	Ave. trees per lot (*n*)	Houses w/o trees per segment (*n*)	Trees replanted (%)
E. Sacramento	Lawn	1,872	39	30 (20–42)	67 (46–88)	54 (39–79)	1.0	4.7	20.6
Land Park	Lawn	1,089	28	30 (1–60)	60 (4–122)	51 (3–88)	1.0	8	33.8
Curtis Park	Lawn	1,054	29	28 (13–44)	68 (30–100)	54 (25–74)	1.1	2	20.7
Oak Park	Lawn	672	24	26 (8–31)	59 (22–68)	59 (12–66)	1.1	4.0	20.6
McKinley Park	D St. planting strip	864	15	30 (14–45)	85 (46–104)	58 (71–87)	1.1	2.0	5.8
Land Park	Planting strip	448	9	25 (2–42)	69 (9–100)	49 (11–77)	1.1	0	44.1
E. Sacramento	Planting strip	416	8	30 (24–44)	51 (37–66)	55 (39–74)	1.2	5.25	47.7
Curtis Park	Planting strip	280	5	24 (15–49)	53 (12–77)	42 (3–76)	1.8	0.5	39.1
McKinley Park	37th St. planting strip	241	5	26 (18–36)	67 (40–88)	54 (41–77)	1.3	3	25.8
Oak Park	Planting strip	416	8	12 (1–63)	33 (8–104)	31 (6–64)	1.3	4.3	78.2

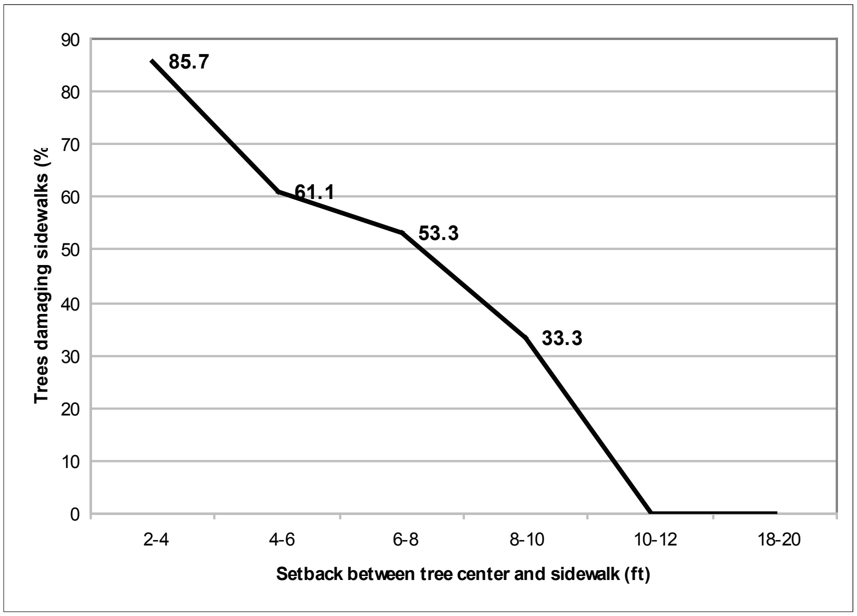


Fig. 18—The percentage of sidewalk damage associated with trees in relation to tree setback from the nearest concrete. A 2- to 4-ft setback in a lawn is equivalent to a 4- to 8-ft planting strip

quality, the existence of hardpan, irrigation history, and tree genetics. Frederick Evans was aware of pervasive hardpan throughout the city and wrote of how crews blasted to break up hardpan layers up to 12 ft below soil surface. He stated they were able to accomplish this without cracking a window in nearby homes (Evans 1938)!

The data also suggest that greenspace of less than 12–15 ft between sidewalks and homes is rarely suitable for planting medium and large species. If a large species is planted in this area, it will need careful monitoring and pruning to keep it from damaging the house until it grows above the roofline (Fig. 19). Trees in these small spaces can be stunted if their root systems are unable to grow beyond or beneath the foundation of the house (not always a good thing) and come into conflict with other built infrastructure. Any healthy tree has as much root volume below ground as it has crown volume above ground. Large trees will grow in small spaces, but the potential for conflict and removal increases. Horticulturalists suggest mentally turning a tree upside down and compressing the branches into a space 2–3 ft deep (the maximum depth for most roots) to give an idea of how much space the tree will take up underground.

Tree Management Planning

Street trees in the park neighborhoods have been planted by the city, developers, gardeners, homeowners, non-profit tree groups, and others. Once these neighborhoods were annexed by the city, the trees were maintained to differing degrees by crews with the City of Sacramento Parks Department.

The majority of older street trees appear to have received regular pruning, as well as spraying for insects and disease, for many years under the direction of park superintendents. Storms in 1938, 1941, and 1950 took a severe toll on trees citywide. Elms, eucalyptus, and other older trees fell and were removed.

In 1947, Superintendent of Parks William Carroll noted that careless location of trees during the previous decades would cost the city more than $250,000 in tree removal costs and mitigation of damage to sidewalks, streets, and gutters (McPherson and Luttinger 1998). New planting rules were adopted and trees were no longer spaced at 20-ft intervals as they once had been downtown. Additionally, smaller trees began being planted in an effort to avoid the extensive storm damage associated with large trees that fell. As mentioned previously, pistache, Modesto ash and zelkova were considered disease-free trees that would be storm resistant.

Carroll's assessment failed to take into account how the planting spaces around the trees had changed over time. In much of downtown, streets were transformed from graded horse and carriage avenues to paved roads for cars and trolleys. The bulk of the trees that fell during the 1938 storm were elms originally planted at 20-ft intervals along streets that had been widened over the previous 15 years to accommodate cars. The widening process cut tree roots, and archival photos show rows of trees toppled toward houses from widened streets. Among the trees that fell in Curtis Park were native oaks and eucalypts planted in the mid- to late 1800s. Neither species tolerates root pruning well.

As with any component of urban infrastructure, the key to avoiding damage or loss lies in adequate planning and design, correct installation, monitoring of condition or health, and periodic maintenance. The second half of this document will provide key ideas and resources for accomplishing this.

Fig. 19—Redwoods planted 10 ft on center from structure. Sidewalks have been modified to increase space and homeowner's driveway has been replaced multiple times. Residents pay for pruning every 2 years to reduce potential for storm damage

In this section we have considered trees from the perspective of history and design. We have worked to understand the factors – species choice, tree size, relations between built infrastructure and trees – that have gone into creating a beautiful and sustainable urban forest over the course of 100 years. To this knowledge we can add another layer of information, described in the next section, about the ecosystem services that trees provide. By combining the two we can create the urban forest of the future that is both beautiful and sustainable and that functions fully to clean our air and water, moderate our weather and climate, and provide a food source and habitat for wildlife.

Section II: Maximizing the Environmental Benefits of Trees

Environmental Benefits of Trees

Trees provide many valuable ecosystem services. Through shade and evapotranspiration, they reduce our consumption of energy. By intercepting and absorbing air pollutants, they help to clean our air. As they grow, they sequester greenhouse gases from the atmosphere. Finally, they work to clean our water, reduce erosion, and slow flooding by intercepting and filtering stormwater runoff.

Table 18 shows the maximum dimensions and potential benefits of the most common large, medium, and small deciduous and large coniferous species in our study of the historic park neighborhoods of Sacramento. From this table we can see the correlation between the level of benefits and tree size. But getting the most out of trees isn't simply a matter of planting a redwood everywhere you can. In fact, the wrong tree planted in the wrong place is at best a nuisance and at worst has negative environmental impacts.

In this section we will describe the ecosystem services that trees provide, how they function to provide those benefits, and how we can design environments that maximize them.

Table 18—Maximum dimensions and potential benefits[a] of the most common large, medium, and small deciduous, and large coniferous species in our study of the historic park neighborhoods of Sacramento

	Mature tree size				Benefit								
	DBH	Height	Crown dia.	Root spread	Energy		Air quality		Greenhouse gases		Stormwater		Total
	in	ft	ft	ft	kWh	$	Lbs	$	Lbs	$	Gals	$	$
Planetree	45	73	66	66	400	46.64	1.48	12.50	380	1.27	1,742	13.59	74.00
Red maple	21	46	42	43	200	23.32	0.65	5.03	182.5	0.61	710	5.54	34.50
Japanese maple	11	27	30	30	100	11.66	0.09	0.79	20.1	0.07	95	0.74	13.25
Redwood	45	103	40	60	450	52.47	1.92	18.70	383	1.28	4,583	35.75	108.20

[a]Calculated using the USDA Forest Service's software program STRATUM (http://itreetools.org)

Energy

In Sacramento, where summers are very hot and energy is a precious resource that is sometimes in short supply, trees perform an especially valuable function by helping to conserve energy (Table 18). They do so by lowering summertime temperatures through shade and evapotranspiration, and by moderating winter temperatures by slowing winter winds (Fig. 20). At the same time, poorly sited trees, in particular evergreen species on the south sides of buildings, can increase energy use by blocking winter sun.

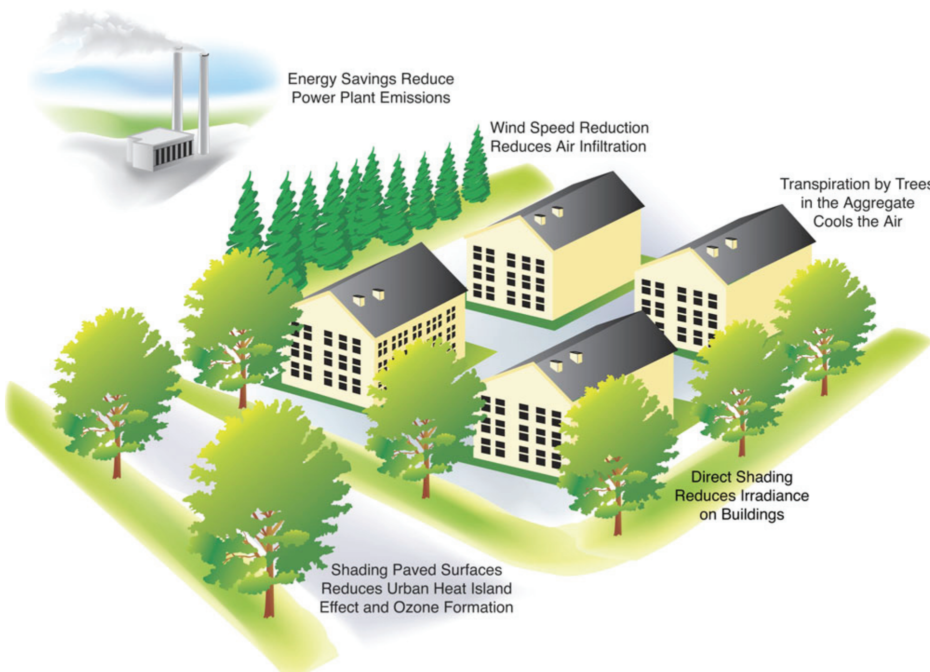


Fig. 20—Ways trees help conserve energy

Air quality

The Sacramento region suffers from some of the poorest air quality in the country, receiving an "F" from the American Lung Association and a ranking of 12th worst in the United States for small particulate matter and 8th worst for smog. Trees play several roles in improving air quality (Fig. 21). They absorb or intercept air pollutants, they reduce energy use by lowering temperatures and thereby reduce the production of pollutants at power plants, and they shade parked cars, thereby reducing evaporative emissions. At the same time, trees can sometimes have a potential negative effect on air quality by producing biogenic volatile organic compounds, a precursor to ozone.

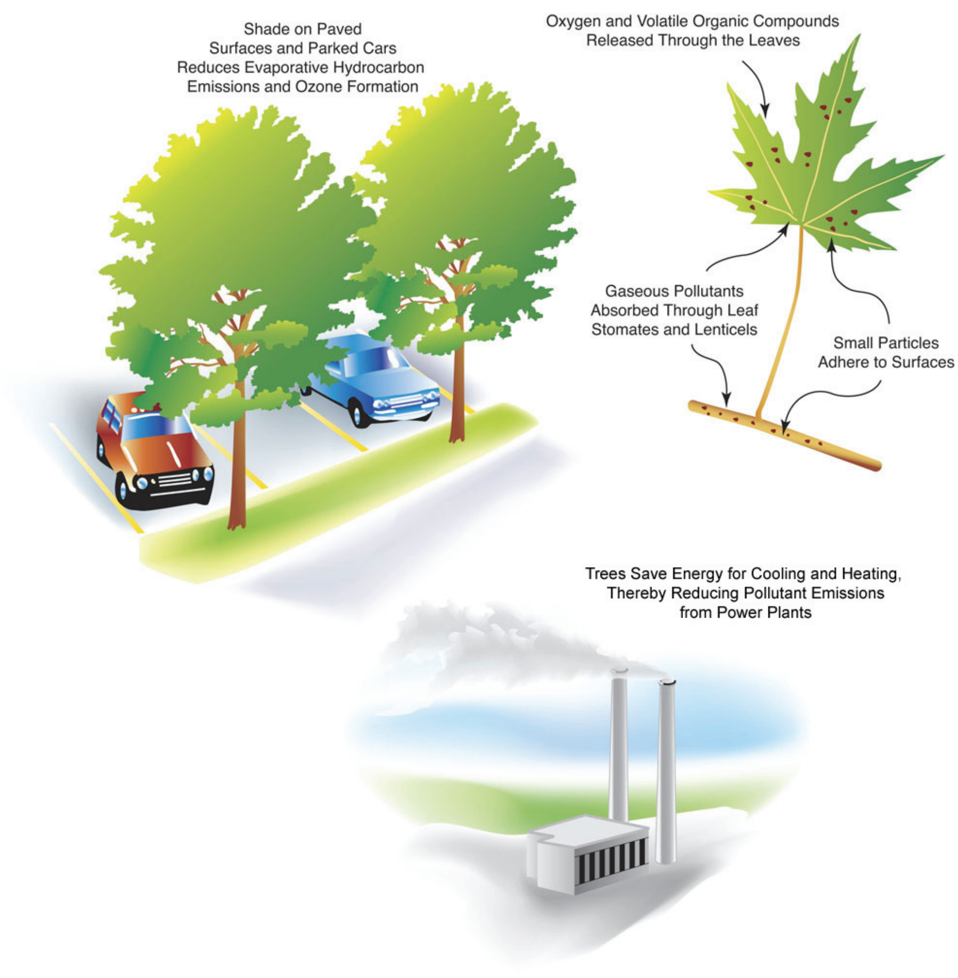


Fig. 21—Ways trees provide air quality benefits

Greenhouse gases

Increasing levels of carbon dioxide and other greenhouse gases in the atmosphere are of growing concern globally and locally. California has pledged to be a forerunner in the fight against global climate change by reducing emissions to 1990 levels by 2020, and trees—especially urban trees—have a role to play. Urban trees reduce atmospheric levels of carbon dioxide and other greenhouse gases in two ways (Fig. 22). First, they sequester carbon from the air as they grow, transforming it into leaves, trunk, branches, and roots. Second, by reducing energy consumption, they reduce the production of pollutants at power plants.

Fig. 22—Ways trees provide greenhouse gas reduction benefits. Tree contributions to atmospheric greenhouse gases are also presented

Stormwater runoff

Nonpoint-source pollution (polluted runoff from diffuse sources) is one of the most significant causes of pollution in our waterways and much of the damage comes from runoff from our streets and chemically treated lawns and gardens (US EPA 2007). Trees can help filter impurities out of stormwater, reduce volume into sewer systems, and reduce peak stream flows (Fig. 23). The hydrological benefits can be greatly increased by planting trees in structural or engineered soil, where the tree-soil complex serves as a mini-reservoir for stormwater.

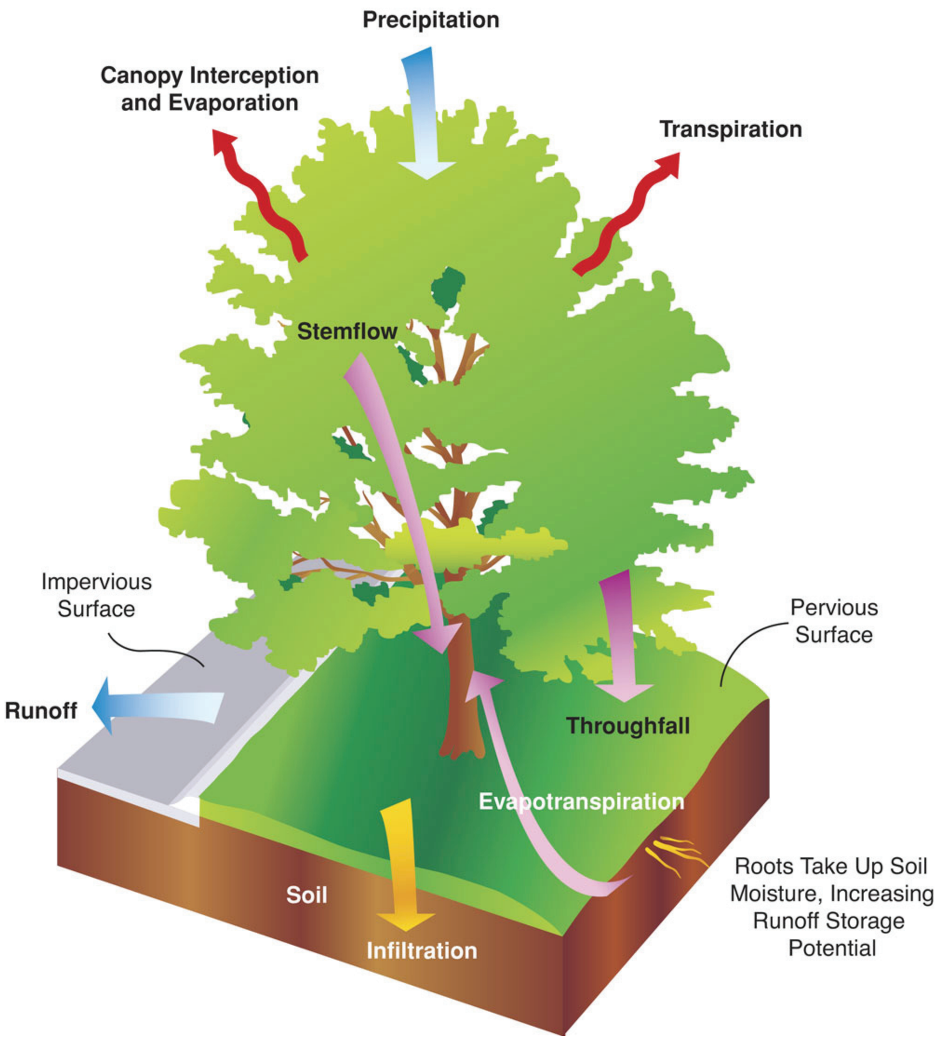


Fig. 23—Ways trees provide stormwater benefits

Habitat

Urban settings are not the barren, natureless places they are sometimes imagined to be. In fact, because of their variety of ecological niches, cities can sometimes support more species of flora and fauna than the surrounding, native conditions, and the transition zone where the city meets areas of open space is often home to the greatest species diversity (Zerbe 2002). Urban trees can serve a valuable role in the ecosystem by providing habitat for local fauna and corridors for movement between natural areas. Landscape design considerations such as the creation of habitat patches and corridors and the size, shape, connectivity, and diversity needed to create a functioning ecosystem are beyond the scope of this report, but even the streetscape can have a role in the broader ecosystem.

Planting Recommendations

It is often said that the secret to growing healthy trees and maximizing benefits is planting the right tree in the right place. Unfortunately this maxim doesn't offer much in the way of practical advice. What is the right tree? What is the right place? In the following sections, we will consider the factors (the *why*, *where*, *what*, and *how*) that define the right tree and the right place in residential areas, commercial districts and parking lots, and transportation corridors.

Residential areas

Why?

Why plant trees in residential areas? There are, of course, many reasons, but in these areas the most valuable focus is on maximizing energy savings and managing stormwater. Because trees in residential areas are located near buildings, they have a doubly beneficial effect on climate: they lower temperatures by directly providing shade and they have a moderating influence on the overall urban climate when they transpire water. And while trees are reducing our energy consumption, they are lowering the production of pollutants and greenhouse gas (GHG) emissions at the power plant, so every kWh of electricity saved not only reduces energy bills and helps in California's perpetual summertime fight to produce sufficient energy, but helps to combat global climate change and improve air quality.

Trees in residential areas also have the opportunity to play a crucial role in water quality by helping manage stormwater runoff. Nonpoint-source pollution (polluted runoff from diffuse sources) is one of the most significant causes of pollution in our waterways and much of the damage comes from runoff from our streets and chemically treated lawns and gardens (US EPA 2007). Trees, especially when combined into a mini-reservoir system with structural soil or planted in streetside retention areas such as bioswales, can capture and treat stormwater naturally before it ever reaches our waterways.

By designing roads, sidewalks, and parking lots to drain toward planting strips, and carefully specifying soil mix based on the existing soil base and expected runoff, trees and their planting strips in new developments could provide a tremendous benefit to the regional water quality.

Where?

Where should trees be planted to maximize energy and stormwater benefits? At the individual site scale, concentrate first on planting trees on the west and east sides of buildings. This will provide cooling shade for walls and windows on the sides of the house that the sun warms most strongly. Avoid planting evergreen or solar-unfriendly trees (those with heavy branching patterns or that retain dead leaves in the winter) on the southern sides of houses as these will block the warming rays of the winter sun.

On streets that run north to south, consider planting broadleaf or coniferous evergreen trees to increase rainfall interception as these trees are in leaf during the rainiest times of the year. A study of the urban and suburban forest of Sacramento (Xiao et al. 1998) showed that the suburban canopy, which was predominantly broadleaf and coniferous evergreens, intercepted twice as much stormwater as the urban canopy, which consisted mostly of deciduous trees. Some deciduous oaks, including the red and scarlet, hold onto their dead leaves all winter and may also be beneficial.

At the larger, ecosystem scale, the goal should be to maximize canopy. Greater climate effects and rainfall interception occur with greater levels of canopy cover. Keep in mind, however, that the first tree shading a structure provides the maximum return on investment. Because additional trees will most likely overlap with the first tree or shade sides of buildings that are less significant for energy conservation, planting second and third trees on properties should be a secondary goal after all unshaded properties have been addressed.

Spacing. Where trees are planted in relation to each other and nearby buildings and pavement has a significant impact on how big they grow. Large trees require a lot of space both above and below ground to reach their full potential. Remember the only thing that makes a bonsai tree so small is that its growing space has been artificially constricted.

Tree to tree spacing. As we have seen in our study of the existing park neighborhoods of Sacramento, trees in several neighborhoods were originally planted with as little as 20 ft between them (Fig. 24). We know from the historical records that trees were systematically removed because they were too close together, but because of the original close spacing and the size of the trees, the canopy remains intact. Planting trees close together offers the advantage of providing more leaf surface area, more canopy, more shade, and therefore more benefits quickly. It is also, in some ways, insurance against the loss of some of the trees. At the same time, trees planted closely together compete

Fig. 24—Trees on Donner Way in Curtis Park are planted as little as 20 ft apart

with each other for nutrients, water and sunlight. Their branching patterns will grow to accommodate neighbors and this might affect the tree's stability.

If trees are planted close together to maximize early canopy, a community management plan must include recommendations on tree removals once the closely spaced trees begin to impinge on one another. This involves additional expense and often meets with the disapproval of residents, who do not wish to have trees removed. Conversely, trees can be planted initially at a distance of 30 to 50 ft, which produces a sparser effect in the early years, but reduces conflicts in the future. The concern in this case is that death of young trees will leave large gaps in the future canopy, so management plans should include provisions for quick replacements.

Tree to structure spacing. There are several things to keep in mind when placing trees near buildings or when selecting the best size species to fit in a particular place. First, to reduce the damage to the foundation from roots and to make maintaining exterior walls and windows easier, it is important not to plant trees too close to a house. A common rule of thumb is that trees should be planted so that, at maturity, their trunks are at least 10 ft from the house. In our study of the historic neighborhoods, however, we noted that street sections where trees were planted 15 ft or less from the house tended to have the fewest trees. Without further study, the reasons for this correlation cannot be exactly determined, but it is plausible that owners removed trees that they felt impinged too closely on their homes. Second, consider the above ground volume that will be available to the tree and match the tree's mature size and form to this space. For example, in front of houses with narrow setbacks to the street, it might be possible to plant a large shade tree, such as an elm, sycamore, or zelkova that can be pruned up to arch gracefully over the house, or a conifer whose lower branches can be raised. Trees with more triangular forms, like that of the magnolia, will be more difficult to fit into very small spaces.

For designs with a planting strip and a narrow setback (< 20 ft), plant one large shade tree in the planting strip. In most cases this will leave sufficient room for one small tree in the front yard (Fig. 25, see also Fig. 4). For designs with a planting strip and a wider setback (35–40 ft), plant a large shade tree in the planting strip. This leaves room for a medium or even a large tree in the front yard (Fig. 26).

Tree to pavement spacing. As we saw in the study of Sacramento park neighborhoods, trees planted in narrow planting spaces (5 ft) were associated with significantly more sidewalk damage than those planted in larger planting spaces or in lawns. Providing trees with insufficient room to grow is not a sustainable practice as it increases costs for pavement replacement, stunts tree growth, and eventually leads to significant damage to roots (see Fig. 9).

Planting strips intended for large trees should be a minimum of 8 ft wide. In the park neighborhoods of Sacramento, even this amount of room led to damage of more than half of sidewalks (see Fig. 18). Consider linear root barriers to encourage roots to grow parallel to the street and sidewalk or use structural soil under sidewalks to allow roots to grow at deeper levels beneath the hardscape. In areas where an 8-ft planting strip is not possible, consider abandoning the planting strip altogether and planting trees in the front lawns as in most of the Sacramento park neighborhoods (Fig. 27) or make use of structural soil.

Fig. 25—Treescape with narrow setback (12 ft) between sidewalk and house leaves room for one large and one small tree

Windbreaks. Individual windbreaks for properties within residential areas are not feasible and also generally not necessary as the conglomeration of buildings and trees in a neighborhood serves to protect residents from the worst impacts of winds. Windbreaks can, however, serve an even more valuable function in creating a air-pollution barrier along traffic corridors. A recent study at Sacramento's Arden Middle School, which sits downwind of the heavily traveled Watt Avenue, showed that the level of fine particulate matter on the school grounds was as high as that along Interstate 5, with significant potential negative health effects for the students (Cahill and the Delta Group 2006). Redwoods, in particular, provide substantial benefits in terms of air pollution, removing 75 to 95% of the most harmful tailpipe exhaust, and are a good windbreak choice.

Fig. 26—Treescape with larger setback (35 ft) between sidewalk and house leaves room for one large and one medium tree

Windbreaks should be considered in new developments as a barrier along major transportation corridors, especially when these border schools, parks and housing areas, and between communities and airports.

What?

Size, type and form. The most significant factor to consider for maximizing energy and stormwater benefits is tree size. Big trees with large amounts of leaf surface area provide the most shade, the greatest climate effects, and the largest area for rainfall interception. Additionally, rough bark, long stems, and leaves that grow parallel to the ground trap more water. Broadleaf and coniferous evergreen trees and deciduous trees that hold onto their leaves during the winter will provide the greatest hydrological benefits. Species with large leaf area, long leaf stems and hairy parts will add extra value as interceptors of air pollution and native species can provide food sources to local fauna.

Fig. 27—The "typical" treescape in the Sacramento park neighborhoods featured trees planted in front lawns

For windbreaks, the ideal tree is evergreen, fast growing, visually dense, with strong branch attachments, and stiff branches that do not self-prune.

The form of the mature tree should be matched to the space available at the site. Where space is limited and trees must be planted close to buildings, plant species such as elms, planetrees, oaks, and zelkova that can be pruned to arch over homes as they grow (Fig. 28). On the south side of buildings, these species also offer the advantage of allowing the low winter sunlight to more easily reach windows and walls.

Species diversity. The question of whether to plant one species or a variety in a given area is a contentious one. Clearly, planting a wide diversity of species reduces the impact that a pest or disease will have. In Minneapolis, after the arrival of Dutch elm disease, the city removed as many as 30,000 elm trees in a year. In the Midwest, an estimated 20 million trees have been killed by an infestation of the emerald ash borer.

On the other hand, blocks planted with one species have an aesthetic appeal that is widely appreciated. Achieving the uniform arching canopy that is desired is easiest with one species, but designers should keep in mind that there are ways it can be created while achieving overall diversity at the larger scale.

Fig. 28—Along Harkness in Land Park, trees have been pruned at a young age to have the form necessary to arch gracefully over homes

- There is little aesthetic advantage to planting the same species on neighboring streets.

Therefore, plant species A on street A, species B on street B…species A on street E, etc.

- The appearance of uniformity can be created by planting different species with similar forms on opposite sides of the street, by alternating species from block to block, or even by alternating from one tree to the next.

- Even on blocks with monoculture plantings, include a few "specimen" trees of other species. These might help slow the spread of disease and will, in the worst case scenarios, mean that some trees will survive a particular infestation. The entrances to each block are especially appropriate places for specimen trees and in our study of the park neighborhoods we saw many examples of this (Fig. 29).

Monoculture plantings create a very formal look. In some areas, a less rigid style might be more appropriate and an interesting mix of species can offer greater diversity with a more forest-like appearance (Fig. 30). This offers the additional benefit of an improved habitat for birds and other fauna.

Fig. 29—In many Sacramento neighborhoods, "sentinel trees" stand at the entrance to each block

A good goal for overall diversity is to have no more than 10% of any one species and no more than 20% of any one genus.

Age diversity. An urban forest with trees of different ages has both economic and health benefits. Trees require the most care and attention at the very early and the very late stages of their lives. When trees are of different ages, the maintenance necessary to care for them, and therefore also the costs, are spread out more evenly over time. Additionally, an uneven aged forest guards against the future loss of all trees at one time. The argument for age diversity also lends weight to the idea of planting trees farther apart initially to allow the spaces between to be filled in over the coming years or even decades.

Fig. 30—A diversity of species creates a less formal, forested appearance along 1st Avenue in Oak Park

How?

How do we plant trees to maximize energy and hydrological benefits? Remember again the most important factor for these benefits is tree size, so, having chosen large species, our goal should be to plant the trees in a way that allows them to reach their full potential. In addition, creating a mini-reservoir from the tree and its soil will allow significantly more rainwater to be intercepted and cleaned.

Mini-reservoirs. It is completely feasible in planning new communities to create a design combining trees and areas of structural soil in a planting strip that captures and treats all runoff from public rights-of-way during all but the most severe storms. For example, the Center for Urban Forest Research has worked with a hydrologist from the Department of Land, Air and Water Resources at UC Davis to design a mini-reservoir for capturing stormwater runoff from a parking lot. Stormwater from the parking lot drains toward a swale planted with London planetrees and filled with Davis soil, a mixture of 75% lava rock and 25% clay-loam soil. The swale provides a growing medium for trees and shrubs and a storage area for runoff, while the soil itself helps trap pollutants as the rainwater filters through it. The system is designed to capture all runoff from a 10-year storm (3.1 inches of precipitation) or 97% of all rainfall events. In initial laboratory results, the Davis soil removed 47–99% of nutrients and 75–96% of heavy metals from the runoff (for more information, see CUFR 2007).

Exact soil mixes and design specifications will depend on the area of impervious surface, the desired design storm requirements to be achieved, and the existing soil.

For more specific details on how to maximize all tree benefits, see "General recommendations for choosing, planting, and maintaining trees" below.

Planting recommendations in commercial areas and parking lots

Why?

Why plant trees in commercial and parking areas? The most valuable and feasible ecosystem services that trees can provide in these areas are reducing energy consumption by ameliorating the urban heat island effect, improving air quality, especially by shading parked cars and thereby lowering hydrocarbon emissions, and managing stormwater. Beyond these environmental benefits, trees in commercial areas have been shown to improve visitors' experiences; shoppers have indicated that they are willing to pay more for parking and up to 11% more for goods in shopping districts with trees (Wolf 1999).

Commercial areas tend to be densely built, with greater amounts of hardscape that absorbs heat and contributes to the urban heat island effect (Fig. 31). Shading these paved and built areas contributes both to reducing energy consumption in the shaded buildings and also has an overall effect on the city's climate. A recent study by Columbia University and NASA found that street trees provide the "greatest cooling potential per unit area" (Rosenzweig et al. 2006). The comfort value of shaded shopping areas in sweltering places like Sacramento cannot be overstated.

At the same time, shading parked cars can have a remarkable effect on air quality. By shading asphalt surfaces and parked vehicles, trees reduce hydrocarbon emissions (VOCs) from gasoline that evaporates out of leaky fuel tanks and worn hoses (for more information, see "Where Are All the Cool Parking Lots?" [Geiger 2002b]). These evaporative emissions are a principal component of smog, and parked vehicles are, surprisingly, a primary source.

Finally, as for residential districts, trees and the soil in which they are planted can serve as mini-reservoirs for stormwater, slowing and filtering runoff before it reaches our waterways.

Where?

Where should we plant trees in commercial areas and parking lots to maximize their ability to lower air temperature, thereby reducing both the urban heat island effect and the air pollutant emissions from parked cars? The

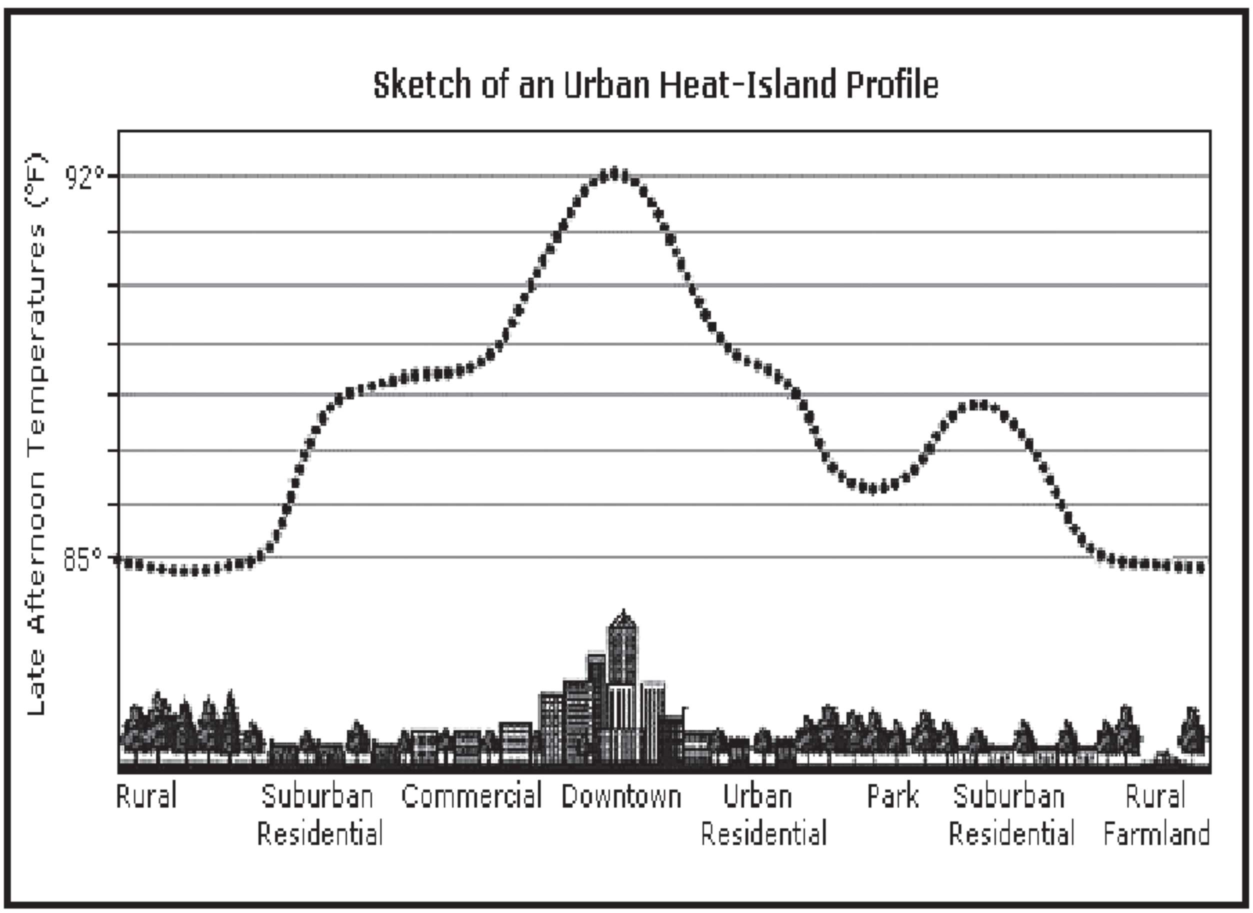


Fig. 31—Paved areas and buildings contribute to higher temperatures in cities. This effect is known as the urban heat island

main goal should be to maximize tree canopy cover over built and paved surfaces. This is clearly a more difficult task in densely built-up areas where space for trees is at a premium, but is certainly possible in even the most dense areas (Fig. 32).

Along commercial streets, shade street parking, sidewalks and bike paths for human comfort and UV protection against the harsh Sacramento summer sun. Focus efforts on planting trees on the west and east sides of buildings. Leaving the south sides of buildings free of shade will reduce energy consumption in winter for heating and will extend the amount of time in the year that shoppers and diners are comfortable outside.

In parking areas, plant trees both on the perimeter and in the interior to maximize shade. There are a number of techniques for creating planting spaces in the interior of parking lots while maintaining the desired number of spaces. For instance, convert double-loaded full-size spaces to compact spaces with a tree in between. This yields a planting space of 8 × 9 ft.

Avoid locating trees where they will block illumination from streetlights or views of street signs, as this will lead to unaesthetic and structurally damaging pruning in the future. To reduce these conflicts, coordinate location of trees, light poles, and signs and reduce the maximum height of parking lot light poles to the height trees are typically pruned for clearance.

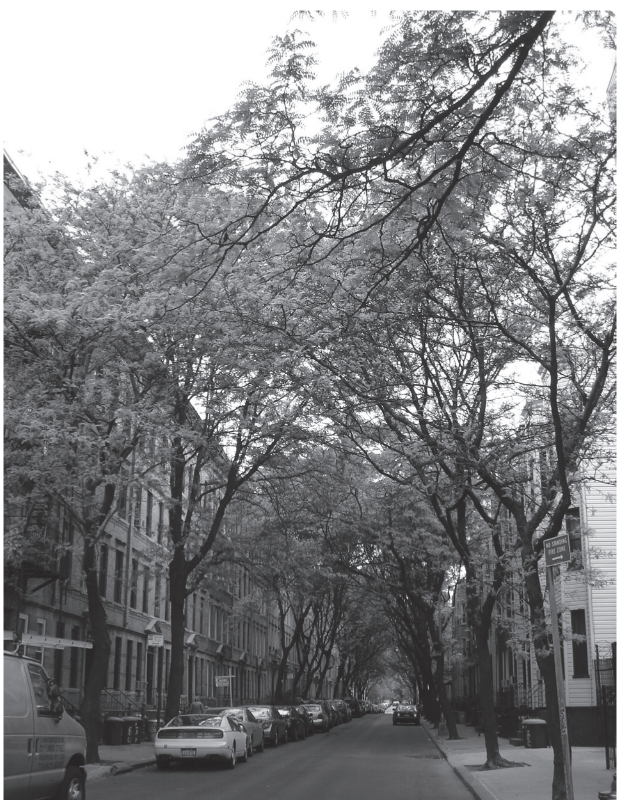


Fig. 32—Trees grow in a very densely built up area of New York City

Spacing. Despite all of our best efforts, it is likely that soil volumes and the supply of oxygen, water, and nutrients to tree roots will be limited in commercial areas. For this reason, trees in commercial districts can be planted more closely together than in residential areas, as these restrictions will limit growth.

What?

Size, type and form. What kinds of trees will maximize the shade and hydrology benefits for commercial and parking areas? Again, size is the most significant concern: the larger the tree, the more area it shades and the more rainfall it intercepts. As the goal is to create as much shade as possible, trees with a wide canopy are most effective. Columnar and other narrow canopy forms should be avoided. Small trees are often chosen for commercial districts with the idea that they won't block signs, but in fact, small tree canopies and signs are usually in direct conflict. Selecting a tree that will grow above commercial signs and pruning it properly when it is young is a more effective solution.

Avoid species with messy or slippery fruit or those that are prone to attacks by pests that will leave vehicles and sidewalks covered with sticky exudates. Trees should be tolerant of hot, dry conditions, and in parking lots strong branch attachments are critical.

Because rooting space is limited, choose species with deep roots to avoid sidewalk damage.

Species with long leaf stems, hairy plant parts, and rough bark will maximize rainfall and air pollutant interception.

How?

Provide trees with the largest possible planting area to maximize growth. A planting space that is 6 × 6 ft or better yet 9 × 9 ft will sustain a much larger tree than one that is 3 × 3 ft, while reducing costs and management difficulties associated with sidewalk and street damage. Where possible, increase the length of the planting strip parallel to the street rather than planting trees in square tree boxes. If larger planting spaces are not possible, the use of structural soil under sidewalks and parking lots will increase rooting space. Successful local examples include the parking lot of RiteAid at Russell Boulevard and Anderson Road and the E Street Plaza, both in Davis (Fig. 33). Linear root barriers should be considered to reduce damage to sidewalks and streets. Pervious pavement, although expensive, can be used sparingly around planting spaces to increase water infiltration and oxygen supply to the roots.

Require soil in tree wells to be excavated to a depth of 3 ft and amended as necessary.

Consider every planting space as an opportunity to create hydrological benefits. As was described above in the Residential section, if runoff from roads and sidewalks is channeled towards tree planting spaces filled with structural soil or designed as vegetated swales it is possible to promote infiltration

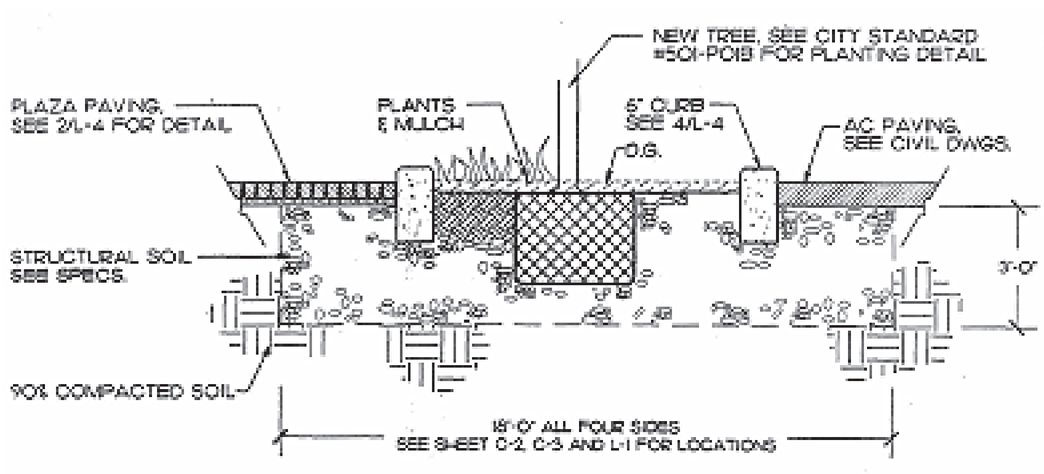


Fig. 33—Specifications for the paving system at the E Street Plaza in Davis, CA. Structural soils provide a base for the pavers while offering tree roots room to grow (Dodge 1999)

and increase soil volume for trees while intercepting and cleaning stormwater from all but the most major storms.

Planting recommendations in transportation corridors

Why?

Why plant trees along transportation corridors? Well-designed thoroughfares for cars or public transportation provide opportunities for mitigating air pollution, reducing the urban heat island effect, and creating habitat for fauna. Furthermore, as discussed above, every tree planted offers the opportunity to capture and treat stormwater, especially if it is planted in either an appropriate structural soil mix or as part of a vegetated bioswale.

Heavily traveled roads create significant amounts of pollution. Sacramento has some of the country's dirtiest air, and vehicles are the single greatest cause of this pollution. As described in the Residential section, some arterial roads can produce emission levels as high as those on multi-lane highways. Trees planted along these roads can intercept pollutants and serve as a vertical barrier that encourages air mixing to dilute pollutant concentrations.

Dark asphalt roads contribute to the urban heat island effect by absorbing heat from the sun. Tree shade reduces this effect while the trees themselves further lower air temperatures as they transpire water.

Because thoroughfares provide a connection between different areas of a development and therefore between different kinds of landscapes, when properly designed they can provide habitat and serve as corridors for the movement of wildlife as well.

Where?

Where should we plant trees along transportation corridors to maximize climate, air quality, and habitat benefits? A well-vegetated buffer between main thoroughfares and public spaces or residential areas will intercept air pollutants while shading the pavement. The spacing between trees should be smaller here than in other areas to create a continuous canopy and a more solid barrier.

What?

For habitat benefit and to guard against widespread loss due to pests or disease, plant a diversity of species, aiming for a multi-layered canopy consisting of large deciduous and evergreen trees with one or even two layers of smaller understory trees. Native trees will offer the food and cover most appropriate for local wildlife and should make up a large part of the plant mix.

Evergreen trees, and conifers in particular, will intercept the most air pollutants and should constitute a significant portion of the buffer. As described above, redwoods have been shown to have the greatest interception rate, capturing 75 to 95% of the most hazardous vehicle emissions.

When considering air quality benefits, it should be noted that some species of trees emit biogenic volatile organic compounds (BVOCs), one of the precursors to smog. The contribution of BVOC emissions from city trees to smog formation depends on complex geographic and atmospheric interactions that have not been well studied. Some complicating factors include variations with temperature and atmospheric levels of nitrogen dioxide. Nevertheless, from a precautionary perspective, choose species that are known to be low emitters of volatile organic compounds where possible.

How?

How should trees be planted along transportation corridors to increase tree health and survival? The same principles described in the sections above and in the general recommendations for choosing and planting trees apply here as well. Provide trees with as much space underground as possible, using Fig. 34 to determine soil volume needs. To avoid conflicts and damage to roads and sidewalks, aim to provide a planting strip at least 15' wide. Even at this distance, in our study of the park neighborhoods, sidewalks showed damage one-third of the time.

Again, consider every planting space as an opportunity to treat stormwater. Vegetated buffers along transportation corridors offer a valuable opportunity to create bioswales to capture and clean runoff from the road.

General recommendations for choosing, planting, and managing trees

Soil compaction. Soil compaction during site grading and construction on new developments is probably inevitable, but measures taken to reduce compaction during construction and to ameliorate damage afterwards will produce large payoffs. Compaction decreases aeration, drainage, water-holding capacity, and root penetration (Craul 1994). Even eight passes with a front-end loader have been shown to increase the bulk density of soils to the critical point at which roots can no longer penetrate, which will severely limit tree growth (Lichter and Lindsey 1994).

Breaking up the compaction after grading using an excavator, a process known as subsoiling, has been shown to have positive effects on tree growth, but the results were dependent on soil type, with trees in the sandy loam per-

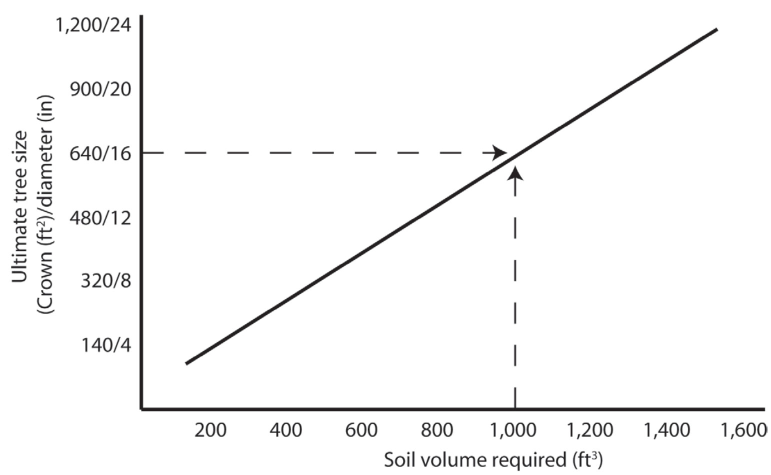


Fig. 34—Developed from several sources by Urban (1992), this graph shows the relationship between tree size and required soil volume. For example, a tree with a 16-inch DBH with 640 ft² of crown projection area requires 1,000 ft³ of soil (from Costello and Jones 2003)

forming much better than those in clay loam (Rolf 1994). Heavily amending compacted soil with commercially available aggregates or organic wastes has been shown to improve soil properties (Patterson 1977, Weir and Allen 1997), but can be expensive. The improvement in tree growth and survival, however, can make it a cost-effective investment.

Soil volume. The area of planting space and the volume of usable soil available to the tree will determine mature tree size (Fig. 35) and providing sufficient soil volume will reduce infrastructure conflicts. Usable soil is that which is available to the tree for root growth. In heavily compacted clay soils this includes only the soil that is broken up during tree planting or during subsoiling as described above.

There are many strategies for increasing the usable volume of soil available to trees while reducing conflicts with infrastructure, including the use of structural soils under sidewalks, alternative sidewalk construction methods, soil amendments, root trenches, and design considerations. For further information including design specifications on these and other ideas, Costello and Jones's *Reducing Infrastructure Damage by Tree Roots: A Compendium of Strategies* is an invaluable resource.

Selecting a tree. Most plantings should consist of species proven to be well-adapted to local conditions plus a small percentage of untested trees that merit evaluation. Fortunately, Sacramento has a climate conducive to many species and there are proven species beyond planetrees that can be planted. The table in the appendix, developed by the Sacramento Tree Foundation's Advisory Committee, includes 90 species rated on the basis of 13 suitability factors including climate adaptation, disease and pest resistance, soil tolerance, and BVOC emissions. Tables like these are a valuable resource for selecting trees to suit local site conditions. This is a partial listing of the rated trees showing predominantly those graded 6 and above, indicating general suitability for the Sacramento region.

Selecting a tree from the nursery that has a high probability of becoming a healthy, trouble-free mature tree is critical to a successful outcome. Therefore, explicit specifications should be provided to those responsible for selecting trees. The very best stock at the nursery should be selected and, when necessary, rejected if it does not meet industry standards. For large scale projects, like new developments, consider having nursery stock grown to specification, ensuring receipt of correctly pruned trees devoid of circling roots.

The health of the tree's root ball is critical to its ultimate survival. If the tree is in a container, matted roots should be checked for by sliding off the container. Roots should penetrate to the edge of the root ball, but not densely circle the inside of the container or grow through drain holes. As well, at least two large structural roots should emerge from the trunk within 1 to 3 in of the soil surface. If there are no roots in the upper portion of the root ball, it is undersized and the tree should not be planted.

Another way to evaluate the quality of the tree before planting is to gently move the trunk back and forth. A good tree trunk bends and does not move in the soil, whereas a poor trunk bends a little and pivots at or below the soil line—a tell-tale sign of a poorly anchored tree.

Planting a tree. It is critical that careful specifications be given to those who will carry out the tree planting. Ideally, those responsible for selecting and planting the trees will also be held responsible for the survival of the tree in its early establishment period. In New York City, for example, contractors must replace any tree that dies within two years of being planted (Peper et al. 2007).

The planting hole should be dug 1 inch shallower than the depth of the root ball to allow for some settling after watering and should be two to three times as wide as the root ball. The sides should be loosened to make it easier for roots to penetrate. The root flare of the tree should come to the top of the soil. If the structural roots have grown properly as described above, the top of the root ball will be slightly higher (1 to 2 inches) than the surrounding soil to allow for settling (Fig. 35).

In windy areas or areas of high traffic, trees might need to be staked. For best growth, it is always best not to staking trees, but in cases where it cannot be avoided, a two-stake system or a reusable commercial product, such as Reddy Stake,[1] should be used. All stakes should be removed after the first year.

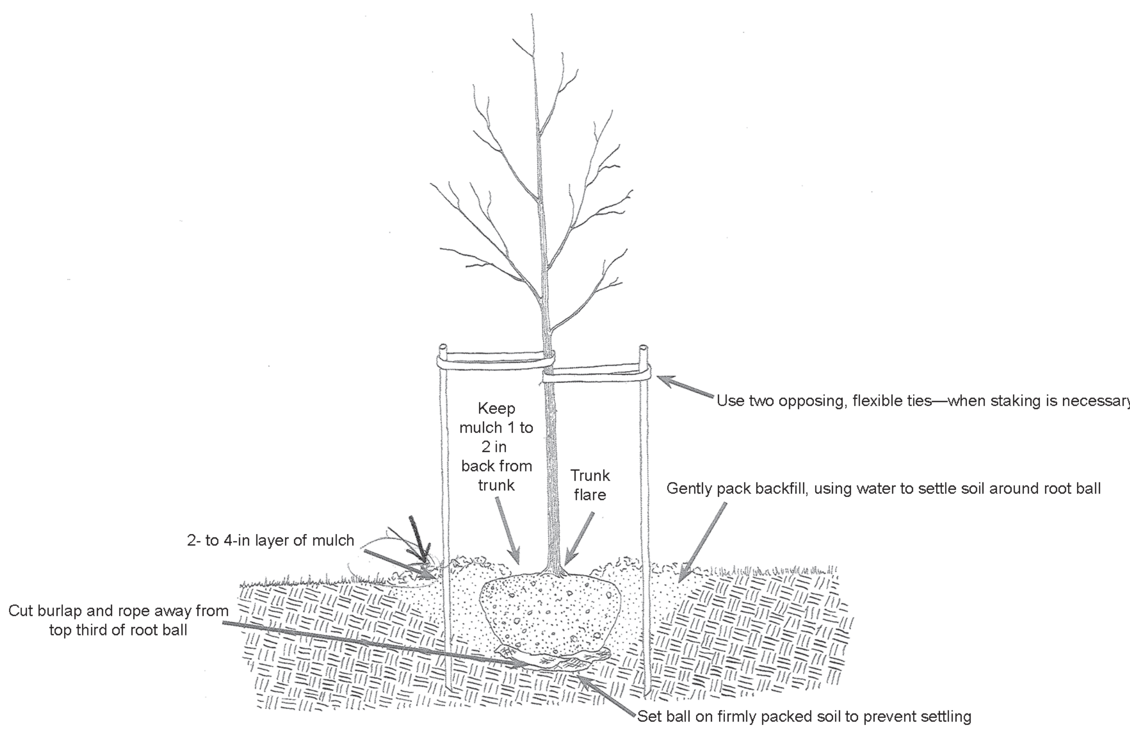


Fig. 35—Prepare a broad planting area, plant the tree with the root flare at or just above ground level, and provide a berm/water ring to retain water (drawing courtesy of International Society of Arboriculture)

[1]The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

For more information, see the Urban Forest Ecosystems Institute's Standards and Specifications (http://www.ufei.org/Standards&Specs.html).

Future management. The most critical period for tree establishment is the first five years after planting. If trees are properly watered and pruned during this time they will be well situated for a healthy and productive future. Trees should be inspected and, if necessary, pruned each year for the first five. After this, pruning should occur as needed on a species-specific basis. For some species, especially those with difficult structures such as pear trees, pruning might be necessary as often as every other year. Other species, if properly cared for in early years, can be inspected and pruned at 8 or even 10 year intervals.

In cases of new development, the responsibility for future management will likely fall to people other than those who originally planted the trees. The level of service afforded to trees will directly impact the benefits they provide. To ensure the future success and stream of benefits from trees, a plan for future management and replacement of dead trees should be drafted and made available to future property owners or neighborhood or homeowners associations.

Conclusions

Nearly all of the people we spoke with in the course of our study of the historic park districts of Sacramento said that it was the trees that had captured their imagination and brought them to the neighborhood. They mentioned the coolness under the canopy in midsummer, the beauty of the branches arching overhead, the birds attracted by the fruits, the light filtering through, and the sense of history and stability the trees brought to the neighborhood.

How can we create the same atmosphere in new neighborhoods? And how can we build on that knowledge to create an urban forest that is not only beautiful and evocative, but that is functional – cleaning our water and air, moderating the weather and climate, providing food and shelter for other species? By studying the patterns of planting and survival over the past 100 years, we have uncovered a great wealth of information about how a sustainable urban forest grows – how much space trees need to reach their full potential, which species stand the test of time, how trees and homes work together to create a forested atmosphere. By combining the historic data with current knowledge about the ecosystem services trees provide and how we can best maximize those benefits, we have the opportunity to create new neighborhoods that offer the best of both worlds: the historic grace of the past and the environmental values of the present.

Recommendations for further reading

General

Reducing Infrastructure Damage by Tree Roots: A Compendium of Strategies by Costello and Jones

Tree Guidelines for San Joaquin Valley Communities by E.G. McPherson, J.R. Simpson, P.J. Peper, and Q. Xiao

Habitat

"Wildlife Habitat Design in Urban Forest Landscapes" by D.A. Milligan Raedeke and K.J. Raedeke

Urban Wildlife Habitats: A Landscape Perspective by L.W. Adams

Native Trees, Shrubs, and Vines for Urban and Rural America by G.L. Hightshoe

Planting

Principles and Practice of Planting Trees and Shrubs by G.W. Watson and E.B. Himelick

Planting Trees and Shrubs for Long-Term Health by R. Hargrave, G.R. Johnson, and M.E. Zins

Soil

Urban Soils: Applications and Practices by Philip Craul

"Urban soils" in the *Urban Forestry Manual* by the USDA Forest Service Southern Center

Hydrology

"Is all your rain going down the drain?" from the Center for Urban Forest Research

Green streets: innovative solutions for stormwater and stream crossings by Metro

The Center for Watershed Protection (www.cwp.org)

Energy

"Save dollars with shade" from the Center for Urban Forest Research

"Green plants or power plants?" from the Center for Urban Forest Research

Air Quality

"Trees—the air pollution solution" from the Center for Urban Forest Research

Web sites

The Urban Horticulture Institute: http://www.hort.cornell.edu/UHI/outreach/recurbtree/index.html

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Urban Forest Ecosystems Institute: Standards and specifications for choosing, planting, staking, and watering trees. http://www.ufei.org/Standards&Specs.html

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Appendix— This is a PARTIAL list of trees suitable for planting in the Sacramento area. Each tree is rated on the basis of 13 suitability factors (1=least suitable and 3 = most suitable). Site conditions and constraints should be evaluated before selecting species for planting. More information on ranking suitability of trees may be found in "Structure and sustainability of Sacramento's urban forests" (McPherson 1998)

Footnote		a	b	c	d	e	f	g	h	I	j	k	l	m	
Weighting		5	5	5	3	3	3	3	3	3	1	1	1	1	
Suitability factor	Tree type	Climate adapted	Dis./pest suscep-tibility	Soil toler-ance	De-gree of litter	Water needs	Prun-ing needs	Branch strength	Root damage potential	Lon-gevity	Avail-abil-ity	BVOC emis-sions	Pollen emis-sions	Aes-thetic value	Average
Acer saccharum ssp. nigrum	BDL	2	1	1	2	2	3	3	2	2	2	3	2	2	5.5
Betula nigra	BDL	3	2	2	3	1	3	1	2	2	3	-	2	2	6.0
Celtis australis	BDL	3	3	3	2	2	2	2	2	3	3	3	1	1	7.1
Celtis sinensis	BDL	3	2	3	2	2	1	2	2	3	3	3	2	1	6.5
Eucommia ulmoides	BDL	3	3	1	3	2	2	3	2	2	2			2	6.2
Gymnocladus dioica	BDL	3	3	3	1	2	1	2	2	3	2	2	1	3	6.6
Liquidambar styraciflua	BDL	3	2	2	2	2	3	2	1	3	3	1	2	2	6.3
Metasequoia glyptostroboides	BDL	3	3	3	2	2	2	2	2	3	2		3	1	6.9
Platanus hybrida	BDL	3	1	3	1	3	3	3	1	3	3	1	1	2	6.5
Platanus occidentalis	BDL	3	1	3	2	2	2	2	2	3	1	1	1	2	6.1
Platanus orientalis	BDL	3	1	3	2	2	2	2	2	3	1	1	1	2	6.1
Platanus racemosa	BDL	3	1	3	1	2	2	3	2	3	2	1	1	2	6.2
Pterocarya stenoptera	BDL	3	3	3	2	2	1	2	1	3	1	-	2	2	6.4
Quercus acutissima	BDL	2	2	2	2	2	3	3	3	3	1		1	1	6.2
Quercus castanaefolia	BDL	3	2	3	2	2	2	3	2	3	1	-	1	1	6.5
Quercus coccinea	BDL	3	2	3	2	2	3	3	2	3	3	1	1	1	7.0
Quercus lobata	BDL	3	3	2	2	3	3	2	2	3	2	2	1	1	7.0
Quercus macrocarpa	BDL	3	3	3	2	2	3	3	2	3	3	-	1	2	7.4
Quercus phellos	BDL	3	3	3	2	2	3	3	2	3	3	1	1	2	7.5
Quercus rubra	BDL	3	2	2	2	2	3	3	2	3	3	1	1	2	6.7
Quercus shumardii	BDL	3	3	3	2	2	3	3	2	3	3	-	1	2	7.4
Tilia americana	BDL	3	2	3	3	2	2	2	2	2	3	-	2	1	6.5
Tilia cordata	BDL	2	2	3	3	2	2	3	2	3	3	-	2	2	6.7
Ulmus americana 'Princeton' *	BDL	3	1	3	2	2	1	1	1	3	2	3	1	2	5.6
Ulmus americana 'Valley Forge' *	BDL	3	1	3	2	2	1	1	1	3	2	3	1	2	5.6

Footnote		a	b	c	d	e	f	g	h	I	j	k	l	m	
Weighting		**5**	**5**	**5**	**3**	**3**	**3**	**3**	**3**	**3**	**1**	**1**	**1**	**1**	
Suitability factor	**Tree type**	**Climate adapted**	**Dis./pest suscep-tibility**	**Soil toler-ance**	**De-gree of litter**	**Water needs**	**Prun-ing needs**	**Branch strength**	**Root damage potential**	**Lon-gevity**	**Avail-abil-ity**	**BVOC emis-sions**	**Pollen emis-sions**	**Aes-thetic value**	**Average**
Ulmus japonica x wilsoniana ‘ Accolade’ *	BDL	2	2	3	2	2	1	1	1	3	1	3	1	1	5.5
Ulmus parvifolia	BDL	3	2	2	2	2	3	2	3	3	3	1	1	2	6.7
Zelkova serrata	BDL	3	2	3	3	2	1	2	2	3	3	3	1	2	6.8
Acer campestre	BDM	3	3	2	3	2	1	2	3	2	2	-	2	2	6.5
Acer rubrum	BDM	3	2	2	2	2	1	2	2	3	3	2	1	3	6.2
Aesculus x carnea ‘Briotti’	BDM	1	3	2	2	2	1	3	3	3	2			2	5.8
Alnus cordata	BDM	2	1	3	3	1	3	2	1	1	3	-	1	1	5.2
Betula platyphylla japonica	BDM	2	2	3	2	1	3	1	2	2	3	-	2	3	6.3
Brachychiton populneus	BDM	2	3	3	3	3	3	3	3	2	3			2	7.4
Carpinus betulus ‘Fastigiata’	BDM	2	2	3	3	2	3	3	3	2	3			1	7.3
Fraxinus pennsylvanica	BDM	3	1	3	2	2	3	2	2	3	3	1	2	2	6.5
Fraxinus texensis	BDM	3	2	3	2	2	3	2	1	2	3	1	2	2	6.5
Koelreuteria bipinnata	BDM	3	2	3	3	2	1	2	3	2	3	1	2	3	6.8
Koelreuteria paniculata	BDM	3	2	2	1	2	1	2	3	2	3	1	2	3	5.9
Laurus nobilis	BDM	3	2	3	3	3	2	2	2	2	2	3	1	1	6.8
Nyssa sylvatica	BDM	3	3	3	2	2	3	3	3	3	2	-	2	2	7.6
Ostrya virginiana	BDM	3	3	3	2	1	3	3	3	3	1		2	2	7.3
Phellodendron amurense ‘His Majesty’	BDM	2	3	3	3	2	2	2	2	2	1		1	2	6.4
Phellodendron amurense ‘Macho’	BDM	2	3	3	3	2	2	2	2	2	1		1	2	6.4
Phellodendron lavallei ‘Longe-necker’	BDM	2	3	3	3	2	2	2	2	2	1		1	2	6.4
Pistacia chinensis	BDM	3	3	2	3	3	1	3	3	2	3	2	1	2	7.2
Pyrus calleryana	BDM	3	2	3	2	2	1	1	2	2	3	3	2	3	6.2
Quercus cerris	BDM	3	3	3	2	2	3	3	3	3	1		1	1	7.4
Quercus douglassii	BDM	3	3	3	2	3	3	3	3	3	1	2	1	2	7.8
Styrax japonicus	BDM	3	3	2	2	2	2	2	3	2	2	-	2	3	6.6

Footnote		a	b	c	d	e	f	g	h	I	j	k	l	m	
Weighting		**5**	**5**	**5**	**3**	**3**	**3**	**3**	**3**	**3**	**1**	**1**	**1**	**1**	
Suitability factor	**Tree type**	**Climate adapted**	**Dis./pest suscep-tibility**	**Soil toler-ance**	**De-gree of litter**	**Water needs**	**Prun-ing needs**	**Branch strength**	**Root damage potential**	**Lon-gevity**	**Avail-abil-ity**	**BVOC emis-sions**	**Pollen emis-sions**	**Aes-thetic value**	**Average**
Acer buergerianum	BDS	3	3	2	2	3	1	2	3	2	2	2	2	2	6.7
Acer griseum	BDS	1	3	2	3	2	3	3	3	1	3			3	6.2
Acer palmatum	BDS	2	2	2	3	2	1	2	3	2	3	2	1	3	6.0
Acer rubrum x freemani ‘Arm-strong’	BDS	3	2	3	3	2	1	2	2	3	2	2	2	2	6.7
Acer truncatum	BDS	2	2	3	3	2	3	2	3	2	1	-	2	2	6.5
Aesculus californica	BDS	3	3	3	1	3	1	2	3	2	3	2	2	2	6.9
Cercis canadensis	BDS	3	3	2	3	2	2	2	3	2	3	3	2	2	7.1
Chilopsis linearis	BDS	3	3	3	1	3	1	2	2	2	3			2	6.4
Chionanthus retusus	BDS	3	2	3	2	2	3	2	3	1	2	-	2	3	7.2
Crataegus phaenopyrum	BDS	3	1	2	3	2	1	1	3	2	3	-	2	3	6.2
Lagerstroemia indica	BDS	3	2	2	2	3	3	2	3	2	3	3	2	3	7.0
Magnolia soulangiana	BDS	2	3	2	2	2	3	3	3	2	3	2		3	6.8
Malus floribunda	BDS	2	2	2	2	2	2	2	3	2	3	3	2	3	6.2
Malus hybrid ‘Prairifire’	BDS	3	2	3	2	2	3	2	3	2	3	3	2	3	7.2
Malus hybrid ‘Robinson’	BDS	3	2	3	2	2	3	2	3	2	3	3	2	3	7.2
Malus ioenis ‘Plena’	BDS	2	1	3	2	2	2	2	3	2	3	3	2	3	6.2
Prunus sargentii	BDS	3	1	3	2	1	3	2	3	1	3	-	3	3	6.2
Syringa reticulata ‘Ivory Silk’	BDS	2	2	3	3	3	3	3	3	2	2			2	6.9
Vitex agnus-castus	BDS	3	3	3	3	3	1	2	3	2	2	-	2	2	7.2
Ginkgo biloba	BEL	3	3	2	2	2	3	3	2	3	3	3	2	2	7.3
Liriodendron tulipifera	BEL	3	1	2	2	2	3	1	2	3	3	1	2	3	6.0
Podocarpus gracilior	BEL	2	3	2	3	2	2	1	3	2	3	3	1	2	6.4
Quercus agrifolia	BEL	3	3	3	2	3	1	3	2	3	3	1	1	2	7.2
Quercus ilex	BEL	3	3	3	2	3	3	3	3	3	2	1	1	1	7.8
Quercus suber	BEL	3	3	2	2	3	3	3	2	3	3	1	1	2	7.3
Quercus virginiana	BEL	3	3	3	2	2	1	3	2	3	3	1	1	1	6.9
Quercus wislizenii	BEL	3	2	2	2	3	1	3	2	3	2	1	1	1	6.3

Footnote		a	b	c	d	e	f	g	h	I	j	k	l	m	
Weighting		5	5	5	3	3	3	3	3	3	1	1	1	1	
Suitability factor	Tree type	Climate adapted	Dis./pest suscep-tibility	Soil toler-ance	De-gree of litter	Water needs	Prun-ing needs	Branch strength	Root damage potential	Lon-gevity	Avail-abil-ity	BVOC emis-sions	Pollen emis-sions	Aes-thetic value	Average
Xylosma congestum	BEL	3	3	3	3	2	1	3	1	3	3	2	3	1	7.2
Magnolia grandiflora	BEM	3	3	2	1	2	3	2	1	3	3	2	3	2	6.6
Pyrus kawakamii	BES	3	1	3	3	2	2	2	3	2	3	3	2	2	6.7
Cedrus deodara	CEL	3	3	3	3	2	3	2	2	3	3	3	3	2	7.8
Pinus canariensis	CEL	2	3	3	3	3	3	2	2	3	3	2	2	1	7.4
Pinus halepensis	CEL	3	2	2	2	3	2	3	2	3	3	3	2	1	6.8
Sequoia sempervirens	CEL	3	2	3	2	1	3	3	2	3	3	2	2	2	7.0

a. 1 = adapted low range, 2 = adapted high range, 3 = well adapted to Sacramento climate (Reimer 1997; Gilman et al.1996 [USDA Hardiness Zone for Sacramento is 9a-9b; Sunset Climate Zone is 14])
b. 1 = pest/disease sensitive, 2 = resistant, 3 = free from pests/disease (Gilman et al. 1996; Reimer 1997)
c. 1 = two or fewer, 2 = tolerates two of three textures and occasionally wet or well-drained, or both drainage regimes and one of three textures, 3 = tolerates all three textures and occasionally wet or well-drained soil (Gilman et al. 1996; Reimer 1997)
d. 1 = severe, 2 = significant, 3 = insignificant (Reimer 1997; Gilman et al. 1996)
e. 1 = high water need, 2 = moderate water need, 3 = low water need (UC Cooperative Extension 2000)
f. 1 = pruning necessary for strong structure, 2 = undefined, 3 = little required (Gilman et al. 1996; TAC)
g. 1 = weak, 2 = medium, 3 = strong (Gilman et al. 1996; Reimer 1997)
h. 1 = high, 2 = medium, 3 = low (Reimer 1996)
i. 1 = life span < 25 yrs, 2 = 25-50 yrs, 3 > 50 yrs (Gilman et al. 1996; Reimer 1997; TAC)
j. 1 = limited availability, 2 = sporadic availability, 3 = generally available (Gilman et al. 1996, TAC)
k. 1 = BVOC emission > 10, 2 = 1-10, 3 < 1 g/g dry leaf wt/hr (Benjamin et al., 1996)
l. 1 = high allergenicity (8-10); 2 = moderate (4-7); 3 = low (1-3) (Ogren plant-allergy scale [OPALS])
m. 1 = not showy, 2 = one showy characteristic, 3 = two or more showy characteristics (Reimer 1997; Gilman et al. 1996)

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