

# **Designing With Climate: Using Parking Lots to Mitigate Urban Climate**

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## **(ABSTRACT)**

Urban areas are known to have different climatic conditions than their rural counterparts including higher temperatures, greater wind speeds, and increased precipitation otherwise known as urban heat islands, urban wind, and urban precipitation. These phenomena are all caused by the design and form of the city. Large amounts of impervious surface area, obtrusive buildings, and a lack of vegetation in the urban landscape all contribute to these problems. Landscape architects have the potential to mitigate urban heat islands, urban wind, and urban precipitation by understanding what causes these phenomena and knowing a few key principles by which to mitigate them.

Parking lots can cover up to half of the land area in cities and offer a great opportunity to correct urban climate problems. This thesis looks at current United States parking lot ordinances to determine if and how well principles of designing with climate have been incorporated. Guidelines are then given to help in the construction of a parking lot ordinance that aims to ameliorate the city's mesoclimate. A design is then created that shows how these parking lot guidelines could be incorporated into a functional, aesthetically pleasing parking lot.

## **Dedication:**

To my grandparents, who think I can do anything.

## Acknowledgements:

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-AHJ

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## **Chapter 1: Introduction**

A trip to the central business district of most cities in the United States will quickly convince the reader that urban climate modification in urban parking lots is, as a general rule, ignored. Parking lots typically are designed to accommodate as many automobiles as possible. The common result is an expanse of asphalt lacking vegetation that negatively affects the urban mesoclimate. This thesis stresses that parking lots can serve as more than just a storage space for automobiles. A well-designed lot wherein climate modification has been considered from the initial design stages will serve as a positive contributor to the urban ecosystem.

The benefits of designing with climate can be divided into the following classifications: environmental, economic, human

health, and sociability of the city. The environmental benefits of climatically sensitive design include improvements in water and air quality. Air quality can be improved by reducing the amount of ground-level ozone and other air pollutants being emitted by automobiles and other man-made machinery (Akbari, Martien, & Rosenfeld, 1992; Huang, Ritschard, Sampson, & Taha, 1992; Spirn, 1984). Water quality will be improved with the introduction of stormwater infiltration areas and vegetation capable of filtering out pollutants (Huang et al., 1992).

The economic benefit of designing with climate is lower energy consumption for the city (Moffat, Schiler, & Staff of Green Living, 1993; U.S. Environmental Protection Agency, 2000). Protecting buildings from extreme heat and cold can reduce the need for heating and air conditioning. Reducing the use of HVAC units also reduces global warming by lowering the amount of pollutants the power plants that run these units release into the atmosphere (Akbari, Davis, Huang, Liu, & Taha, 1992).

Designing with climate can also improve the health of the city dweller (U.S. Environmental Protection Agency, 1997; U.S. Environmental Protection Agency, 1998). Designing with climate can increase urban ventilation and cleanse the city of many airborne diseases. Reducing air temperatures in the city during summer months can also help to reduce the occurrence of heat-related illnesses. Designing with climate also reduces lower-level ozone pollution, a cause of serious health risks for children, the

elderly, and those with asthma (U.S. Environmental Protection Agency, 2003).

Finally, the quality of community life can be enhanced by designing with climate (Spirn, 1984). Creating comfortable spaces for pedestrians can help to encourage more sociable cities and improve the lifestyle of its inhabitants. Lengthening the time of year in which people may comfortably remain outdoors will help to enrich urban life by allowing for a greater amount of activities.

It is important for designers to realize that the design of a site affects the microclimate of that site and can make an impact on pedestrian comfort within that site. Designing with climate in only one site, however, will have little effect on the mesoclimate of the city. In order to have a noticeable effect citywide, multiple sites within the city must be designed to improve climate.

Three major phenomena account for most climatic problems in the city: urban heat islands, urban wind, and urban precipitation. The goal for the landscape architect, when designing with climate, is to decrease the negative effects these phenomena have on the city and its inhabitants. This can be accomplished by learning what causes these phenomena and understanding the relationship between them and the physical form of the city. Urban heat islands, urban wind, and urban precipitation are all caused by high amounts of impervious surface coupled with the lack of vegetation found in urban areas (Akbari, Davis, et al., 1992).

Therefore, decreasing the amount of impervious surface area and increasing the amount of vegetation throughout the city are key aspects of designing with climate.

Impervious surfaces in the city include buildings, roads, and parking lots. The use of greenroofs on buildings to reduce impervious surface area in the city is already receiving a great deal of attention and will not be discussed within this paper. Parking lots and streets can cover 35% to 50% of the land in U.S. cities (Levinson, 1982). Parking lots alone can cover from 6% to 40% of our downtown central business districts as Figure 1.1 illustrates (Childs, 1999). With so much of the city being devoted to the storage of cars, parking lots appear to be the logical place for landscape architects to begin to reduce impervious surface area and increase vegetative cover within the city. Eliminating the contribution of parking lots to urban heat islands, urban wind, and urban precipitation has the potential of reducing those climatic phenomena by, up to, one half. It is for this reason that parking lots have been chosen as the main focus for this thesis.

This paper provides a review of the literature on designing with climate as well as a review of selected U.S. parking lot ordinances. The parking lot ordinances selected have been indicated in the literature review as ordinances that promote climate improvement. Findings from the literature and ordinance case studies are then used to create guidelines for developing a

generic parking lot ordinance for the Mid-Atlantic region of the United States that places a strong emphasis on improving urban climate.

One reason for choosing the Mid-Atlantic region is that, according to the U.S. Census Bureau (2003), this region has one of the fastest growing populations in the United States. This population growth creates the need for new developments. To prevent these new developments from aggravating urban climate problems, measures need to be taken to ensure they are designed in a climatically sensitive way. Creating and enforcing adequate parking lot ordinances in the city are one way to control this expanse in development.



Charleston, SC



Norfolk, VA



Savannah, GA



Washington, DC



Wilmington, NC

*Figure 1.1. Percentage of Cities Devoted to Parking Lots. Aerial photos of Mid-Atlantic cities showing the amount of area devoted to parking lots. Central business districts are outlined in red with parking lots highlighted in yellow.*

## **Chapter 2: Impacts of Failure to Design With Climate**

Historically, cities and villages were designed based on the local climate. Before mechanized heating and air conditioning was available, architects had to rely on building design and the layout of villages to naturally cool buildings and outdoor open spaces. Vitruvius (1914) and Palladio (1977) wrote books on the best way to lay out villages in order to naturally heat and cool buildings and open spaces. These design ideas were forgotten after the Industrial Revolution and cities would simply become clusters of buildings and roads with little or no attention given to designing with climate.

The design of a city can have a great impact on its climate. The 1970's energy crisis in the United States brought about the need to study the city, its form, and how that form may have an effect on climate. Urban climates are known to be very different from rural climates. Annually, urban areas can "have an average of 12% less solar radiation, 8% more clouds, 14% more rainfall, 10% more snowfall, and 15% more thunderstorms than their rural counterparts" (Taha, 1997, p. 1). Three phenomena occur in urban areas caused by the layout and form of the city: urban heat islands, urban wind, and urban precipitation.

Many times architects, landscape architects, and urban planners are only concerned with site specific microclimate and give little attention to the affect their designs have on the mesoclimate of the city. Golany (1996) suggests that climatic character should be considered at two major levels when designing city spaces: the microclimatic scale (single site) and the mesoclimatic scale (entire city). A working knowledge of how climate is affected by the form of the city is necessary in order to understand what changes will occur at the site scale.

Along with a knowledge of how form affects climate, it is also vital to understand how climate affects the pedestrians who use that space. Understanding the human body's physiological responses to thermal stimuli will assist the landscape architect in designing a more thermally comfortable urban landscape.

### Human Thermal Comfort

The American Society of Heating, Refrigerating and Air-Conditioning Engineers Handbook (1992) defines thermal comfort as "that condition of mind which expresses satisfaction with the thermal environment" (p. 1). The majority of research on human thermal comfort has revolved around indoor environments which have fairly stable climates (Givoni, 1963; Olgyay, 1963). The constantly changing climatic conditions of the outdoor environment make designing for human thermal comfort much more difficult. The overall concepts and factors determining thermal comfort, however, are the same for both indoor and outdoor environments and can be used to estimate a person's comfort in the outdoor open spaces of the city.

The human response to the thermal environment is impossible to express as a function of only one environmental factor (Givoni, 1963). Several factors go into determining human thermal comfort including: air temperature, wind, humidity, metabolic rate, age, sex, and clothing levels. All of these elements will differ from person to person and place to place, making it difficult to please everyone all the time.

Warner (1991) suggests that landscape architects should design spaces to create optimal thermal comfort or comfort for the majority. When designing for optimal thermal comfort, one should try to eliminate climatic extremes because these are the

conditions pedestrians most want to avoid. This means designing to provide cooler spaces in the summer and mitigating harsh elements, like strong winds, during the winter.

Radiant air temperature and wind are the two factors that designers have the greatest ability to manipulate and will be the two climatic aspects covered here. The amount of radiation and wind a person comes into contact with can drastically affect that person's thermal comfort levels (Spirn, 1984).

Radiant air temperature is the temperature created by the radiant heat exchange from one surface to another. Any object with a temperature greater than  $-459^{\circ}\text{F}$  ( $-273^{\circ}\text{C}$ ) emits radiant energy (Brown, 1982). The second law of thermodynamics states that energy will flow from an object of greater energy to one of lesser energy until those energy levels are equaled. A cool object will absorb heat energy from any object warmer than itself, thereby warming the cooler object, and cooling the warmer object. So, radiant air temperature is the temperature created by a surface gaining or losing radiant energy to the air.

The air above an asphalt parking lot, for example, is hot in the summer because the asphalt is radiating heat energy from itself into the air directly above it, creating warmer air temperatures. This warm air is then absorbed by pedestrians using that space, assuming that the air temperature is warmer than the pedestrian's body temperature. This can cause the pedestrian to feel uncomfortably warm.

Wind is the second climatic element that can and should be manipulated by the landscape architect in order to create more thermally comfortable spaces. Wind has the ability to carry heat energy either to or from a given surface. On a hot summer day, a breeze comes as a pleasant relief as it carries heat energy away from the body leaving the body feeling cooler. The effect of wind on human thermal comfort during the winter will have the opposite effect as it increases the rate at which the body loses heat. Wind itself does not change the actual temperature of the air surrounding the body, it only speeds the transfer of heat from the body to the air.

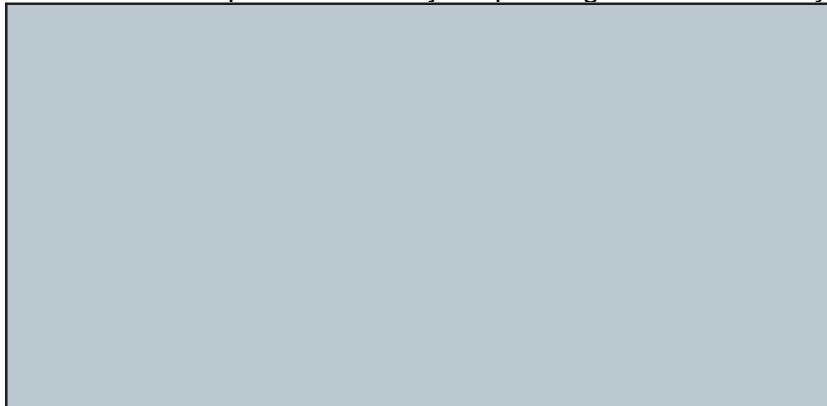
The energy between a person and their environment must be equalized in order for that person to be comfortable (Brown, 1982). The variable outdoor climate makes it impossible to create a constant balance of energy, but efforts can be made to decrease the energy difference. By mitigating elements that have the greatest effect on body temperature, landscape architects have the ability to extend the length of time that pedestrians use a site throughout the year.

#### Urban Heat Islands

Studies have shown that temperatures can be  $2^{\circ}\text{F}$  to  $8^{\circ}\text{F}$  warmer in cities than in the surrounding countryside (Akbari, Davis et al., 1992). For more than a century, climatologists have been studying this phenomenon known as the urban heat island effect.

The degree of temperature increase due to the heat island effect varies from city to city depending on the climatic region of the city as well as its physical characteristics. A tightly clustered city in a cool region like New York City, for example, can be up to 10°F warmer than its surrounding countryside. Tropical cities, like Mexico City, experience the greatest heat island effects and can be up to 18°F warmer (Akbari, Davis et al., 1992). While this temperature rise may be a welcomed effect during cold winters, the warmer summers create conditions that are uncomfortable to pedestrians and lead to higher energy consumption in order to cool buildings.

The primary causes of urban heat islands are higher concentrations of air pollution, automobiles, heat-producing machinery, and impervious surfaces, as well as lower amounts of vegetation (Akbari, Davis et al., 1992). Air pollution can influence heat island buildup in different ways depending on the time of day.

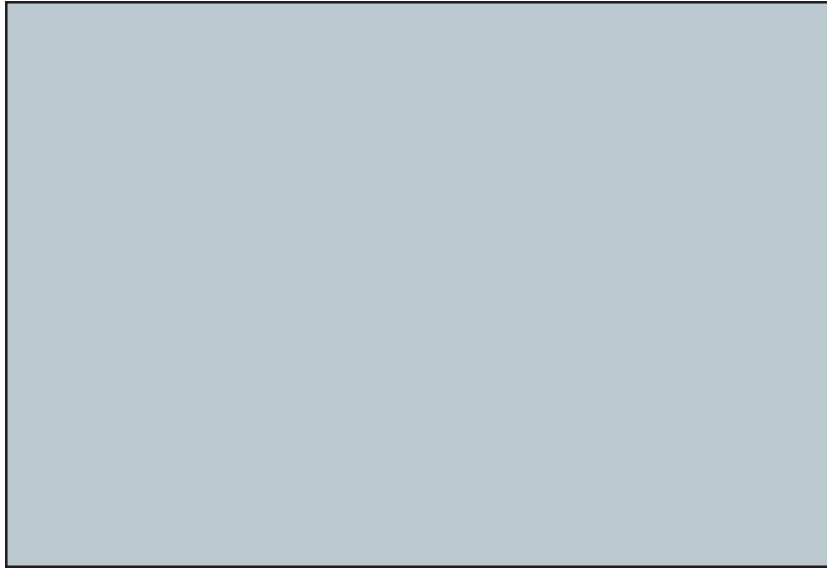


*Figure 2.1. Urban Heat Island Profile.  
Source: Akbari, Davis et al., 1992.*

Atmospheric pollution acts as a dome surrounding the city. During the day, this pollution reflects more radiation back into space meaning less solar energy will reach the earth's surface, therefore, reducing heat island buildup. After sunset, however, just the opposite occurs; pollution traps heat in the city, preventing it from escaping back into the upper atmosphere (Akbari, Davis et al., 1992). The use of automobiles and heat producing machines such as HVAC units, add to the amount of pollution in the atmosphere.

Dark, impervious surfaces, such as buildings and roads, absorb most of the solar radiation that comes into contact with them and store that heat energy for long periods of time until it can be released. The overwhelming heat storage capacity of paved, impervious surfaces may be the greatest contributor "to the magnitude and evolution of the heat island" (Asaeda, Ca, & Wake, 1996, p. 425). The amount of solar radiation that a surface is capable of absorbing depends on that surface's albedo.

The albedo of a surface is determined by measuring the amount of solar radiation reflected from a surface and then measuring the amount of solar radiation coming into contact with that surface. The ratio of the two is the albedo. In other words, a surface with an albedo of 0.1 is reflecting 10% of the solar radiation coming into contact with it and absorbing the other 90% (Pomerantz, Pon, Akbari, & Chang, 2000). A general rule of thumb is that dark colored or wet surfaces have lower albedos while light colored or dry surfaces have higher albedos. Asphalt, for



*Figure 2.2. Examples of Urban Albedos.  
Source: Akbari, Martien et al., 1992.*

example, may have an albedo as low as 0.05 while fresh snow may have an albedo as high as 0.9 (Lynch & Hack, 1984).

Albedos not only indicate how much radiation a surface absorbs, but also how rapidly that surface releases radiant heat. “Albedo may therefore be imagined as the relative permeability of a surface to radiant energy flowing in either direction” (Lynch & Hack, 1984, p. 46). Surfaces with a low albedo radiate heat energy more rapidly than a surface of high albedo.

Studies have been conducted to determine the amount of cooling energy that could be saved by using surfaces of higher albedo on buildings and roads. An average albedo change of 0.07 can result in a decrease of up to 3.6°F while higher modifications

in albedo (0.13) can lead to an increase of 6.3°F (Taha, Douglas, & Haney, 1997). This study also showed that such a change would reduce electricity demands which could help lower the heat island effect in urban areas by reducing air polluting emissions.

The lack of vegetation in urban areas exacerbates heat islands as vegetation helps to cool the surrounding air through a process called evapotranspiration. Evapotranspiration is the process in which a plant, tree, or shrub absorbs water and nutrients into its system through the roots and uses what it needs for growth. Any excess water the plant does not need is converted to water vapor and transpired into the surrounding air. The conversion of water to water vapor uses heat energy and helps lower the surrounding air temperature.

These cooling effects, however, are most pronounced where trees are planted in groups, not singly (Heisler, 1986). The effects of evapotranspiration are most noticeable in arid climates like Davis, California where temperatures in neighborhoods with mature trees can be 3°F to 6°F cooler than neighborhoods with young or no trees (Huang et al., 1992).

#### Urban Wind

Urban wind is a condition created by high-rise buildings, the relatively smooth surfaces of cities, and large amounts of open spaces. Wind is the movement of air from areas of high pressure to areas of lower pressure. Wind speed is determined by the

difference of the two pressures; the greater the difference in pressure, the faster the wind speed. Air movement is also caused by temperature differences as air moves from cooler areas to warmer areas. The physical form of urban areas has a large effect on wind speeds and patterns.

Buildings and surface roughness alter wind patterns in various ways. Upper level winds will be slowed due to drag caused by buildings of various heights. Wind in rural areas moves freely at higher elevations, but when that wind reaches the city and comes into contact with taller buildings, it is slowed considerably.

Lower level winds are more dramatically affected by city form. Buildings alter wind by creating solid barriers through which wind cannot penetrate. When wind meets a solid surface, like that of a building, it is forced to find another path in which to flow. This causes wind to move in unpredictable patterns and creates higher air pressure around the buildings, increasing wind speeds. The taller the building, the more noticeably the wind speed increases. Wind tunnel studies have shown that buildings up to four stories have the ability to shelter the city and its streets from uncomfortable winds. High rise towers, on the other hand, will increase city wind speeds by up to 150% making it difficult for pedestrians to navigate (Bosselmann, 1998).

Unlike buildings, open spaces allow wind to penetrate easily with little friction. The smooth surfaces of roads and parking lots in the city create little friction for the wind, compared to the tree-

filled landscape of the countryside. If aligned improperly, the building-lined streets of the city can act as wind flumes allowing winds to reach top speeds.

The way in which wind behaves within the city is difficult to predict. Without wind tunnel testing, there is no way to predict wind turbulence, direction, or speed within the varying built patterns. Designers can use wind tunnels or water flumes to show how a section of a city will react to wind and make decisions based on the findings. Bosselmann (1998) has suggested that the best way to reduce urban wind is to mimic natural settings. The skyline of the city should look more like rolling mountains than a choppy clustering of blocks. This will reduce the amount of blunt objects wind comes into contact with, allowing wind to flow smoothly over the city.

#### Urban Precipitation

The third phenomenon that occurs in cities is urban precipitation. Studies have shown that urban areas receive more precipitation than rural areas (Taha, 1997). This precipitation is diverted into stormwater systems, carrying pollutants from roads and parking lots with it. The excessive amounts of stormwater could then cause flooding and pollution problems in lower stream systems.

Landsberg (1981) explains that there are several factors that cause increased precipitation in cities. The first cause is the

urban heat island effect. Heat islands produce a constant rise of warm air which leads to the formation of clouds. As these clouds rise, they begin to collect water vapor. The higher the clouds rise, the cooler the air becomes, condensing the water vapor and creating rain.

The second cause for increased precipitation in cities is urban wind. As discussed earlier, when upper level wind reaches the tall buildings of the city, wind speed decreases. This wind decrease will slow the movement of precipitation systems over the city, increasing the amount of rain a city receives.

The third cause of urban precipitation is increased pollution in cities. Pollution contributes to cloud formation in cities and these clouds could lead to precipitation. Exactly how much of an effect pollution has on urban precipitation has yet to be determined. The exact degree of increased precipitation in cities is also difficult to determine because of the unpredictability and unevenness of precipitation systems (Landsberg, 1981). This unpredictability makes it difficult to compare rain accumulation in different areas because precipitation systems do not continuously release a consistent amount of rain.

Urban heat, wind, and precipitation are the result of urban design decisions and increased concentrations of polluting machinery and industries. The use and placement of different

construction materials will result in different climatic situations. Knowing how specific materials will influence climate leads the designer to draw conclusions on how to correct urban climate problems.

## **Chapter 3: Principles for Designing With Climate**

One way for cities to improve the quality of pedestrian life is to design to ameliorate urban heat islands and urban wind, as well as take better measures to compensate for higher levels of precipitation. Lowering the amount of impervious surfaces (especially those of lower albedo), and increasing vegetative cover will reduce near-ground air temperatures and temperatures of those areas downwind from the site (Taha et al., 1997). The following principles will focus mainly on the redesign of parking lots to reduce their negative effects on urban climate.

### Heat Mitigation

Urban heat can be drastically reduced by modifying heat-absorbing, impervious surfaces throughout the city (Akbari, Martien et al., 1992). The temperature of an outdoor surface is mainly due to the amount of solar radiation that a surface absorbs. Surface temperatures throughout the city can be lowered by using alternative surfaces with higher albedos, using more permeable surfaces, and using vegetation to shade surfaces from solar radiation.

#### *Amount of Impervious Surface Area:*

Perhaps one of the best ways to reduce the impact impervious surfaces have on climate is to reduce the overall impervious surface area of the city. Cities could try and cut back on the amount of paving that occurs in downtown areas. Surface parking from several lots could be combined into one parking garage with a greenroof. Not only would this lessen the amount of impervious area within the city, but those vacant lots could then be turned into small pocket parks, adding extra vegetation to the urban landscape.

#### *Surface Albedo:*

The contribution of roads and parking lots to urban heat islands can be dramatically reduced if materials of higher albedo are used in their construction. Studies estimate that if “the sunlight

absorbed by all the pavements [within the city] were reduced from 90% to 65%, the peak air temperature would decrease by about 1°F (0.6°C)” (Pomerantz et al., 2000, p. 2).

Using surfaces of higher albedo, like concrete as opposed to asphalt, will reflect, rather than absorb the majority of solar radiation that comes into contact with it. This is not to say, however, that concrete is the best material for city paving. The reflected solar radiation from concrete can be absorbed by neighboring buildings and passing pedestrians. Asaeda, Ca, and Wake (1996) tested various paving materials and their effects on the lower atmospheric air temperature. The study showed that asphalt surfaces, as well as their surrounding air temperatures, were much warmer in late afternoon and during the night hours than concrete surfaces. Temperatures taken at noon, however, found the air temperatures above concrete surfaces to be much higher than those above asphalt surfaces. This is due to the high reflectivity of concrete surfaces to solar heat. To avoid both of these situations, designers may want to choose a surface with an albedo in between that of black asphalt and concrete.

The albedo of surfaces can be altered by resurfacing pavements with colored seals. Chip-seals are often used to cover asphalt surfaces to give them a lighter color and decrease their heat absorption.

### *Porous Surfaces:*

One of the reasons that the countryside remains cooler during the summer is that water is constantly being evaporated from subsurface levels, cooling the air above it (Davis, Martien, & Sampson, 1992; Huang et al., 1992). This process is lost under the impervious materials of the city as surfaces are designed to drain water into stormwater systems instead of allowing it to percolate into the ground. Removing that water causes the city to forgo on a great opportunity for natural evaporative cooling. Paving with surfaces that are permeable to the exchange of water from surface to subsurface, and vice versa, will allow this process to take place.

Porous pavements are materials that allow water and air to move through them. There are three basic types of porous pavements that are commonly used in areas such as parking lots. These include: concrete-lattice grass pavements, plastic-lattice grass pavements, and porous pavements of asphalt or concrete (Pomerantz, Akbari, Chen, & Taha, 1997).

The first two pavement types are made with grass and some type of supportive frame. Using grass instead of traditional paving materials will help to create an environment similar to the rural landscape. Water is easily absorbed into the ground and the cooling effects of evaporation will be felt in the surrounding air. These types of pavement also lead to cooler above ground air temperatures as the grass absorbs and uses heat energy in the

process of evapotranspiration. This type of porous pavement would be well suited in an area that does not receive heavy daily traffic like a residential driveway or church parking lot.

Asphalt or concrete porous pavements allow for the penetration of water through their surfaces into an underground holding area until that water can be absorbed into the ground or evaporated back into the atmosphere. The flow of water through porous pavements occurs in both directions facilitating the evaporative cooling process. These types of pavements permit heavy traffic and are feasible to use in most situations.

It should be noted, however, that, as with any design decision, local needs must be considered. This includes the local climate. Porous pavements may increase the amount of humidity in a parking area because of the evaporation that occurs over these surfaces. Cities which already have high rates of humidity may wish to avoid adding more humidity to the air and, therefore, may want to avoid porous pavements.

### *Vegetation:*

Trees can be used in urban areas to intercept solar radiation before it can be absorbed by impervious materials. Vegetation shades heat-absorbing surfaces and also helps to cool air temperatures through evapotranspiration, especially when trees are located in large groups. The more vegetation that is provided in parking lots, the greater the cooling effects of evapotranspiration

will be felt.

The shade created by trees can also improve urban heat islands by reducing air pollution. Shading cars in parking lots can reduce the amount of hydrocarbons that are evaporated from gas tanks, therefore, reducing air pollution and heat islands (Scott, Simpson, & McPherson, 1999).

#### Wind Mitigation

Urban open spaces and buildings should be designed to facilitate summer cooling by permitting breezes while minimizing chilling winds in winter. Summer and winter winds generally prevail from different directions, allowing for the design of both. While it is impossible to predict how the installation of a new building will affect wind patterns without wind tunnel testing, it is possible to design roads and parking lots to ameliorate wind by following a few basic principles.

Vegetation can be used as wind barriers on the periphery of open spaces or next to buildings. Closely planted evergreen shrubs create screens which can divert winter winds over or around buildings and open spaces. Evergreen barriers can also be used to direct winds into a space during the summer for cooling. Vegetation can also be used to decrease wind speeds. Planting vegetation along streets and within parking lots and open spaces will create drag, slowing wind speeds through the city.

#### Precipitation Mitigation

The two major causes of urban precipitation are urban heat and urban wind, therefore, designing to reduce urban heat and urban wind is the best strategy landscape architects can use to reduce urban precipitation. Beyond that, landscape architects can only design to accommodate excessive stormwater. Providing on-site filtering and storage of stormwater will reduce problems associated with urban precipitation. This can be accomplished by using porous surfaces and/or vegetated filter strips. Both solutions allow for the slow infiltration of stormwater while removing pollutants. Allowing stormwater to percolate into the ground will also help to recharge the groundwater system.

The use of vegetation in the urban environment can also help to mitigate the amount and rate of falling precipitation. Trees slow the impact velocity of precipitation, expediting infiltration and evaporating some precipitation back into the atmosphere (Trowbridge & Bassuk, 2004).

#### Vegetation in the Urban Landscape

As shown, vegetation has the potential of making an impact on all three urban climate phenomena. The inclusion of vegetation within the city creates an environment more similar to that of rural areas where such phenomena do not exist. In order to make noticeable improvements in urban climate, however, trees must

reach significant sizes. Rarely do trees reach these sizes in urban areas, especially along roadways and in parking lots. Many trees do not live for more than their first two years and the average street tree lifespan is approximately ten years (Day, Bassuk, & van Es, 1995). The reasons for this poor survival rate are improper planting techniques and little or no maintenance.

Parking lots provide harsh growing conditions for plants. More attention is given to making a paved surface that will last over time than ensuring the presence of vegetation. The typical parking lot design creates desert-like soils that are extremely compacted lacking any of the nutrients or water that plants need to survive (Whitcomb, 1987).

Some of these unfavorable conditions can be relieved by implementing the principles for mitigating urban heat islands. Porous pavements, for example, will allow for the transfer of oxygen and water to subsoils for root growth. To ensure the survival and health of urban vegetation, information needs to be provided on planting techniques and maintenance guidelines for vegetation in parking lots. Municipalities must require that vegetation be planted and maintained in an acceptable manner. Appendix A provides more detailed information on the needs of urban vegetation and discusses proper planting techniques and maintenance guidelines. These requirements can be enforced through parking lot ordinances and will be discussed further in the next chapter.

The design principles outlined in this chapter should be used to help ameliorate the extreme climatic elements within the city. These principles can be easily incorporated into the design of the city to reduce the effects of urban heat, urban wind, and urban precipitation.

Educating the public on the benefits of designing with climate is one way to encourage the implementation of the above design strategies. Cities can also include these principles in their zoning ordinance in order to require the use of climatic design strategies in parking lot development. The following chapters will look at some examples of current parking lot ordinances to determine if and how well these principles are currently incorporated.

## **Chapter 4: Parking Lot Ordinances**

Traditionally, parking lot ordinances have been used to require developers to provide ample off-street parking for employees and customers. This requirement helps to alleviate traffic congestion on the street and promotes the welfare of local businesses by making driving more convenient for the consumer (Longstreth, 1992; Owens, 1978). Off-street parking facilities, however, can lead to unwanted problems for the city like the creation of “dead space” along city streets as well as an increase in impervious surface area, which exaggerates urban climate problems.

The overall purpose of city ordinances is to promote the health, safety, and welfare of the public. Because ordinances have

the ability to regulate the design of buildings, roads, and parking areas, they offer a great opportunity for cities to begin a climate control program. The scope of ordinances should be expanded to include the reduction of urban climate problems.

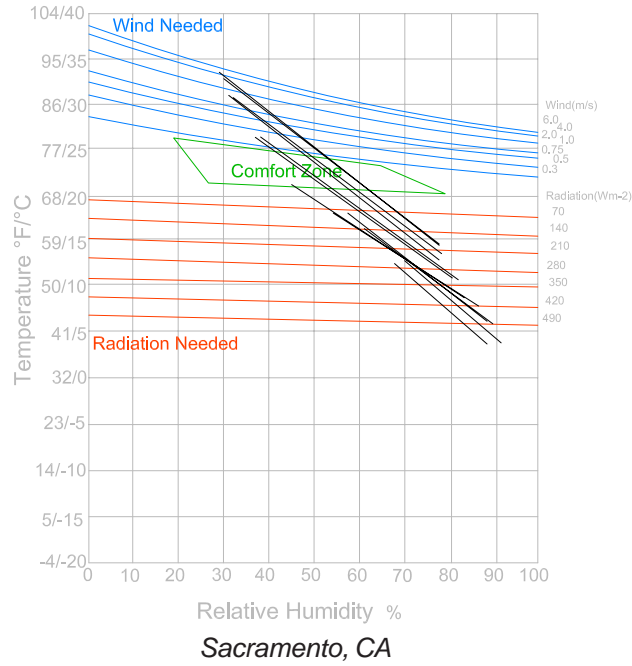
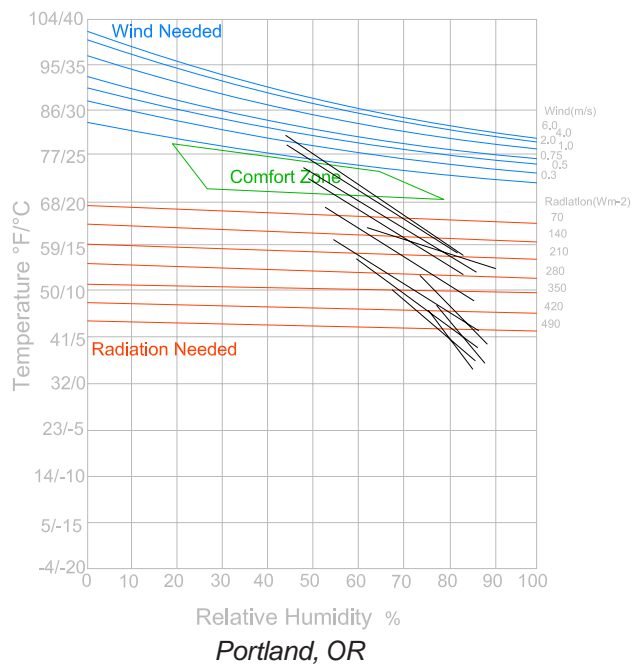
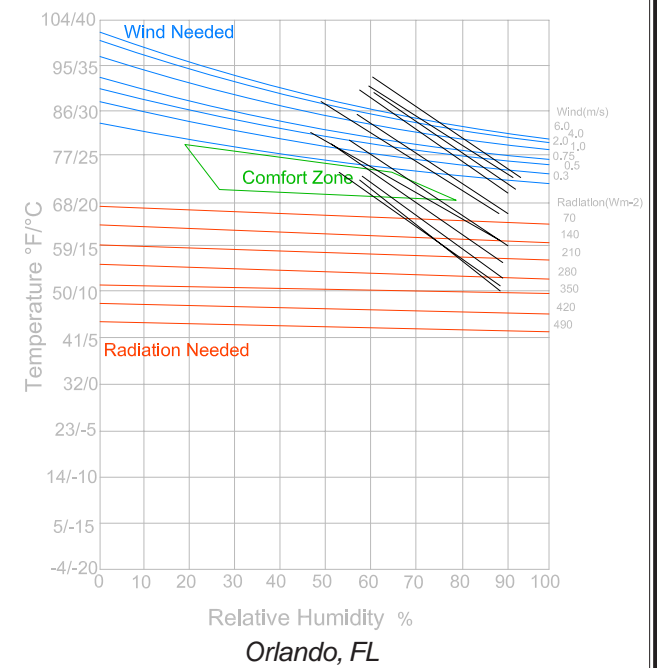
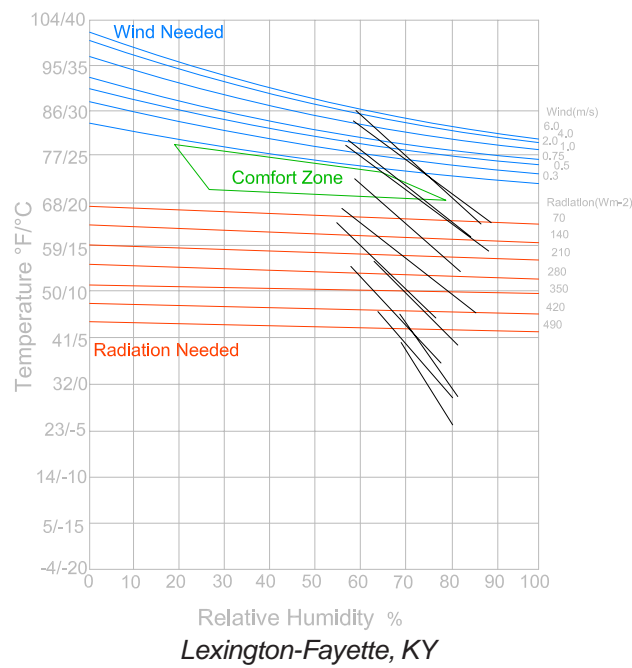
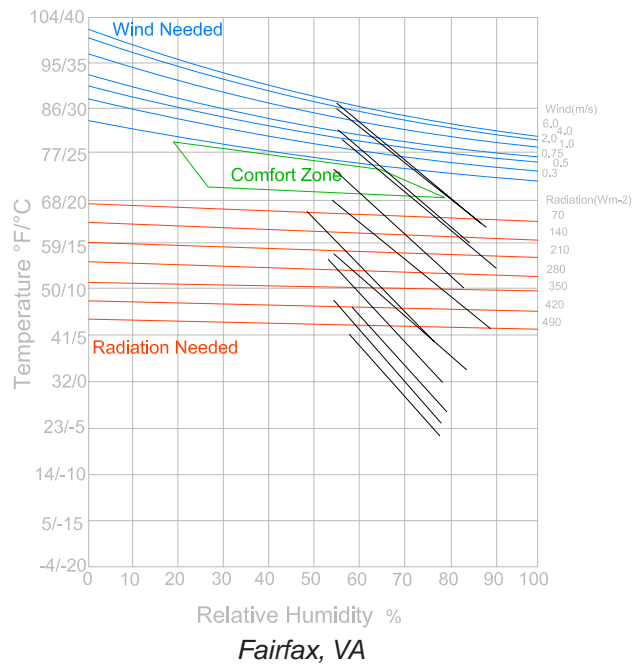
A review of the literature on parking lot ordinances and parking lot landscaping highlights a group of cities that all have climate improvement as a major objective in their parking lot ordinances (Corwin, 1978; Smith, 1988; Wolf, 2004). The cities chosen include: Fairfax, Virginia; Lexington-Fayette County, Kentucky; Orlando, Florida; Portland, Oregon; and Sacramento, California. These cities are located throughout the United States in a variety of climatic regions. The parking lot ordinances from these cities are studied below and analyzed for their content to determine how adequate they are at improving the mesoclimate of the city.

Principles of designing with climate from the previous chapter are used as the basis for examining the parking lot ordinances in order to determine their potential for mitigating urban heat and urban wind. Because urban precipitation is the direct result of urban heat and urban wind, separate mitigation strategies for urban precipitation are not needed in the parking lot ordinance. Cities, however, may want to encourage the use of infiltration beds in their parking lot ordinances in order to help control excessive stormwater.

### The Climatic Adequacy of U.S. Parking Lot Ordinances

Before an adequate analysis of the ordinances can be made, a climatic study of the cities must be done. Bioclimatic charts have been used in designing with climate since the mid-1900s. The purpose of these charts is to illustrate the effect of local climatic conditions on human comfort. The charts include variables such as air temperature, humidity, solar radiation, and wind. Within this chart lies an area designated to be the range of human comfort based on a person of normal activity level and typical clothing types. Once a city's air temperature and humidity levels are drawn on the chart, the designer can see how often and when the city's temperature falls within the comfort zone. The chart also illustrates ways to extend the comfort zone by adding wind or solar radiation and how much of each would be needed.

A bioclimatic chart has been created, based on historical weather data, for each of the cities chosen for this project (Figure 4.1). As expected, the bioclimatic charts show that the climates of the selected cities vary greatly. Sacramento and Orlando have climates that remain near the comfort zone for most of the year while the other cities have a much broader climatic range. These bioclimatic charts can be used to influence the creation of parking lot ordinances by illustrating which areas of climate mitigation will need to be stressed for that particular city.



*Figure 4.1. Case Study  
Bioclimatic Charts. Adapted  
from Lynch & Hack, 1984.*

The results of this climatic analysis will be used to help determine the adequacy of the following parking lot ordinances. A matrix (Table 4.1) of the case study parking lot ordinances has been created in order to compare their content and Figure 4.2 is used to illustrate these ordinance requirements.

*Heat Mitigation:*

Reducing the amount of impervious surface area in cities should be a major goal in designing with climate. Orlando, Portland, and Sacramento all regulate a maximum number of parking spaces that can be provided in parking lots depending on the use that lot serves. It is unclear whether maximums are determined based on local needs or national surveys.

Fairfax, Orlando, and Sacramento permit the use of alternative paving materials allowing for the use of porous pavements. Orlando allows for parking lots to remain unimproved for parking areas that are infrequently used. A second reason for allowing unimproved lots is for the protection of existing trees within the parking area.

Landscaping is required in all five ordinances, but in different fashions. Lexington-Fayette, Orlando, and Portland require a percentage of landscaping based on the size of the lot. Fairfax requires a specific number of islands based on the number of parking spaces in the lot. Landscaping requirements for these four cities means only required island area, not amount of

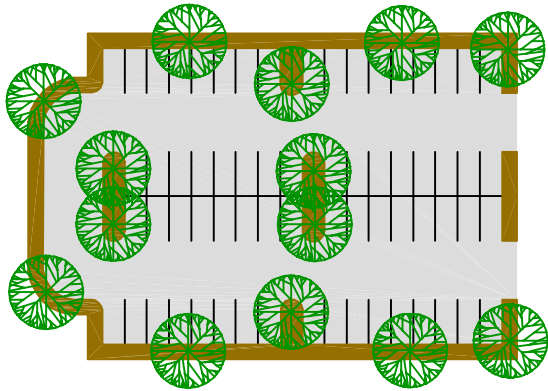
vegetation. Each ordinance has a separate requirement for the number of trees to be provided based on the required amount of island area.

Sacramento, on the other hand, requires a specific percentage of shading to be created within a specified time frame. While the provision of landscaping in the lot may slightly cool the air, the greatest cooling benefit comes from the creation of shade. It may not be sufficient to only require a specified number of trees within the parking lot for several reasons. First, different types of trees will result in a different amount of shade. Second, since trees rarely reach mature heights in the urban landscape, they may never provide sufficient shade but are still able to satisfy the code requirements by simply remaining in the parking lot. Requiring a percentage of shade forces the developer to plant and maintain trees that will grow to provide adequate shade. The requirement of a specific amount of shade within a parking lot may be the most straight-forward way for a city to ensure that adequate shading requirements are met.

Sacramento was one of the first cities to enact a parking lot shading ordinance and has since received a great deal of attention in determining its effectiveness. The requirements of the parking lot ordinance are that 50% of the parking lot area had to be shaded within 15 years of completion. McPherson (2001) studied Sacramento to see how many of the city's parking lots were meeting the requirements of 50% shade cover. He found that the

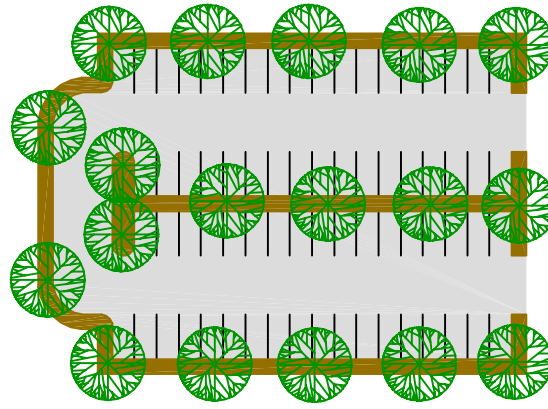
	<b>Ordinance Requirements</b>	<b>Fairfax, VA</b>	<b>Lexington-Fayette, KY</b>	<b>Orlando, FL</b>	<b>Portland, OR</b>	<b>Sacramento, CA</b>
<b>Heat Mitigation</b>	landscaping	1 island per 12 parking spaces	5%	2.5%	10%	–
	shade					50% w/in 15 years
	distance between islands	≤12 parking spaces	≤120 feet	≤100 feet		
	# of trees	≥1 per island	1 every 250ft <sup>2</sup> of landscaping	1 tree point per 100ft <sup>2</sup> of landscaping	1 every 120ft <sup>2</sup> of landscaping	
	size of parking lot			regulates max. size	regulates max. size	regulates max. size
	surface type	permits alternative paving				
<b>Wind Mitigation</b>	perimeter screen height	≥30"	3'	30"	3'	3'
	perimeter trees	1 per 500ft <sup>2</sup>	every 40ft	3 tree points per 100ft	every 30ft	
<b>Planting Standards</b>	island size	min. 9ft by 18ft	regulates min. and max. size	min. 5ft radius from tree	regulates min.	regulates min.
	island type		recommends clustered		strips between parking rows	recommends clustered
	tree size at planting	regulates min.			regulates min.	
	planting instructions		manual illustrates planting methods	meet current nursery standards	meet current nursery standards	manual illustrates planting methods
	-soils		√			√
	-drainage		√			√
	-irrigation			√	√	√
	-mulching	√	√	√		
<b>Plant Maintenance</b>	growth management	maintain healthy, growing condition	weed, remulch, maintain irrigation system	maintain irrigation system		
	-pruning		manual provides instruction	prune as needed	prune as needed	manual provides instruction
	-topping			prohibited	prohibited	
	-fertilization		manual provides instruction			manual provides instruction
	damage management	protect from cars	protect from cars	protect from cars	protect from cars	protect from cars
	insect & disease control		manual provides instruction			manual provides instruction

Table 4.1. Matrix of Case Study Parking Lot Ordinances.



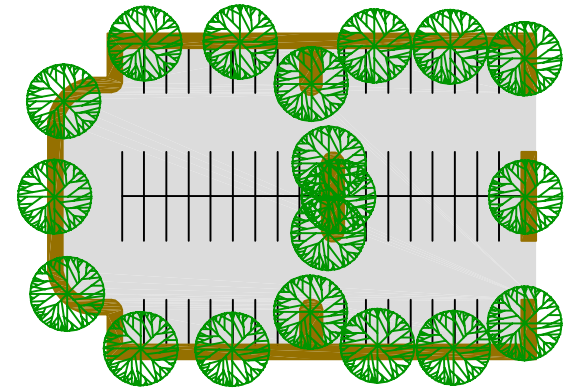
**Fairfax, VA**

- Interior:*  
 -1 island (9'X18') per 12 parking spaces  
 -1 tree per island
- Perimeter:*  
 -screens at least 30" high  
 -1 tree per 500ft<sup>2</sup> of buffer required



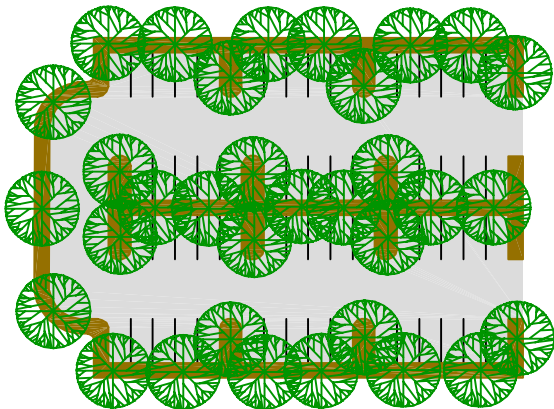
**Lexington-Fayette, KY**

- Interior:*  
 -5% landscaping  
 -1 tree per 250ft<sup>2</sup> of landscaping
- Perimeter:*  
 -screens at least 3' high  
 -1 tree every 40'



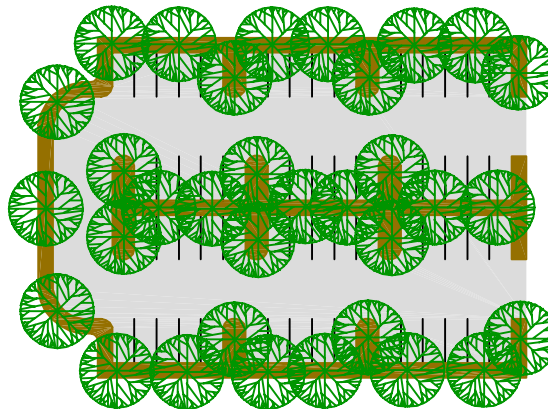
**Orlando, FL**

- Interior:*  
 -2.5% landscaping  
 -1 tree point per 100ft<sup>2</sup> of landscaping
- Perimeter:*  
 -screens at least 30" high  
 -3 tree points every 100'



**Portland, OR**

- Interior:*  
 -10% landscaping  
 -1 tree per 120ft<sup>2</sup> of landscaping
- Perimeter:*  
 -screens at least 3' high  
 -1 tree every 30'



**Sacramento, CA**

- Interior & Perimeter:*  
 -50% shade within 15 years
- Perimeter Screens:*  
 -at least 3' high

Figure 4.2. Illustration of Case Study Parking Lot Ordinances.

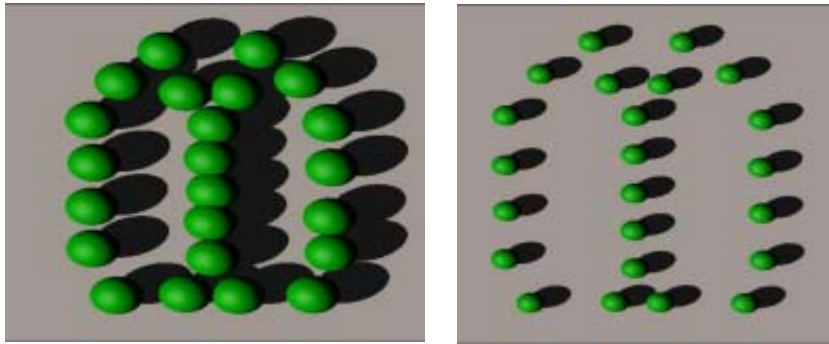


Figure 4.3. Study of Sacramento Parking Lots. McPherson's study showed that after 15 years, the stunted trees in Sacramento's parking lots produced less than half of the shade required.

average shade coverage on parking lots after fifteen years was 22%, less than half of what was required (Figure 4.3). He goes on to list some possible reasons why shading requirements were not met. These include:

- Overlapping tree shade being counted twice in the shade estimation provided on the tree plans.
- Planners and designers using trees that were not on the recommended tree list resulting in trees that are not capable of providing the required shade.
- Crown dimensions on the plan being overestimated.
- Crown dimensions in the tree list being overestimated suggesting that certain trees would reach a specific diameter at fifteen years that those trees were incapable of meeting.
- Trees that were drawn on the plans not being installed or being removed shortly after installation.

- Trees that were not listed on the plan being used instead of those that were listed.
- Parking lot areas being built to hold more spaces than were allowed by the ordinance.

Since this study, Sacramento has modified its parking lot shading ordinance to increase the likelihood of parking lots reaching their goal of 50% shade in 15 years. Some of the changes include providing a more complete tree list and requiring that the majority of trees used in the parking lot come from that list. Steps have also been taken to better enforce and monitor parking lots in order to ensure that the end result looks as it should based on the landscaping plans approved by the city. The biggest improvement Sacramento made was providing examples of how to calculate shade in a parking lot. Sacramento's current parking lot tree shading ordinance has been provided for reference in Appendix B.

#### *Wind Mitigation:*

All of the ordinances require interior landscaping in the form of trees, shrubs, and ground covers which will create drag and slow wind speeds. Perimeter landscaping is also required by all five cities and has the greatest potential to modify wind. Perimeter landscaping requirements include a wall, fence, and/or vegetated screen along the edge of the site to a height of at least thirty inches. Depending on the adjacent use, the requirement

for perimeter screens may reach up to eight feet tall. All ordinances also require trees to be installed at varying distances along the perimeter.

While all of the ordinances included requirements for vegetation that could have an effect on wind, those requirements were not included for that purpose. Required screens along the perimeter of the parking lot are solely for the purpose of screening views between the parking lot and neighboring buildings and/or roadways. While visual screens may be an important aspect in parking lot design, wind mitigation also needs to be considered when specifying requirements. Taking both objectives into account will result in more appropriate screens.

The type of screen required in parking lots will depend mainly on the local climate of the city. Cities like Orlando, for example, may choose not to require screens, or require the lowest screen possible, because cooling breezes will be welcomed year round. Fairfax, on the other hand, with its cold winters, may want to require a more clustered perimeter landscaping screen in certain cases in order to lessen the intensity of winter winds.

*Planting Standards and Maintenance Guidelines:*

All five parking lot ordinances include varying amounts of information on planting standards and maintenance guidelines. Minimum island sizes are regulated by each city and all cities require that landscaping be protected from automobile

encroachment. Lexington-Fayette, Portland, and Sacramento are the only cities that recommend or require clustered planting or planting strips between rows of parking spaces. Only Orlando and Portland prohibit tree topping in their tree ordinances. In general, no parking lot ordinance included all of the necessary planting standards and maintenance guidelines discussed in Appendix A.

Lexington-Fayette and Sacramento stood out among the rest by providing a supplemental manual on planting and maintenance standards. One of the reasons Sacramento began to provide this information was because of the lack of initial success their shading ordinance was having in parking lots. A large part of the problem was that trees were not reaching their ideal sizes and, therefore, were not producing the expected percentage of shade (Figure 4.3).

The manuals also allowed the cities to include specific planting techniques without cluttering the parking lot ordinance itself. These manuals provide room for the cities to include drawings that illustrate planting standards, drainage strategies, pruning instructions, and design suggestions. Providing manuals outside of the parking lot ordinance appears to be a clear and concise manner in which to regulate vegetation planting and maintenance guidelines.

The most noticeable finding in the comparison of these

ordinances is that even though their climates are so different they are all relatively similar in their requirements. Some of the requirements, like shade coverage, should be a similar goal throughout the United States. But because the cities studied are all from different climatic regions, the ordinances should be noticeably different in other areas. Orlando, for example, would want to encourage year-round breezes through their parking lots and possibly forgo perimeter screens while Fairfax and Lexington-Fayette will want to require more screens to limit winter winds.

The use of porous pavements is another area that may differ from region to region. While evaporative cooling does have the potential to cool above ground air, it also adds to humidity levels. Higher humidity levels in the southeastern region of the U.S. would create more uncomfortable conditions for the pedestrian and would want to be avoided. In these areas it may be more suitable to require a specific albedo range in which paving should fall than to recommend the use of a permeable surface.

#### The Climatic Adequacy of Mid-Atlantic Parking Lot Ordinances

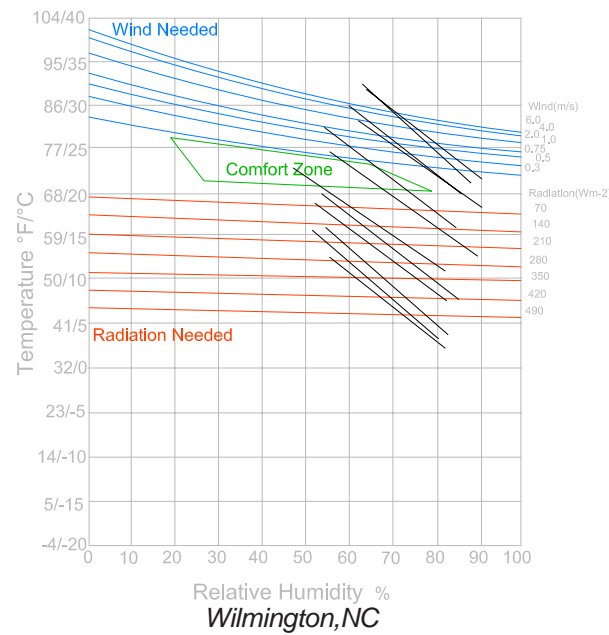
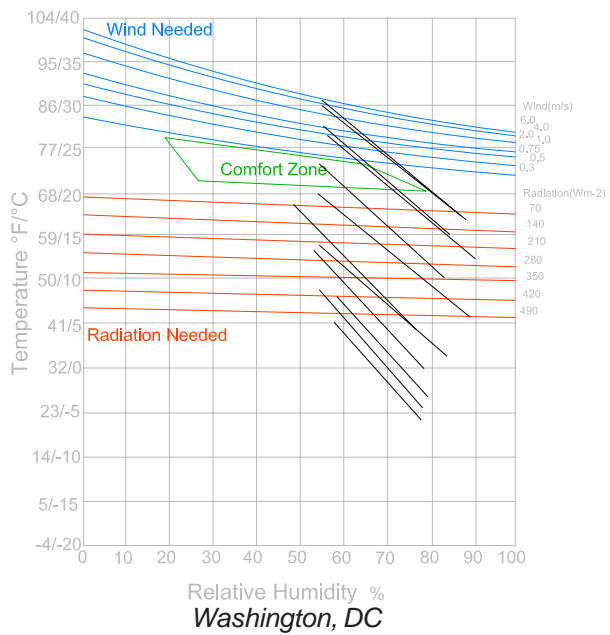
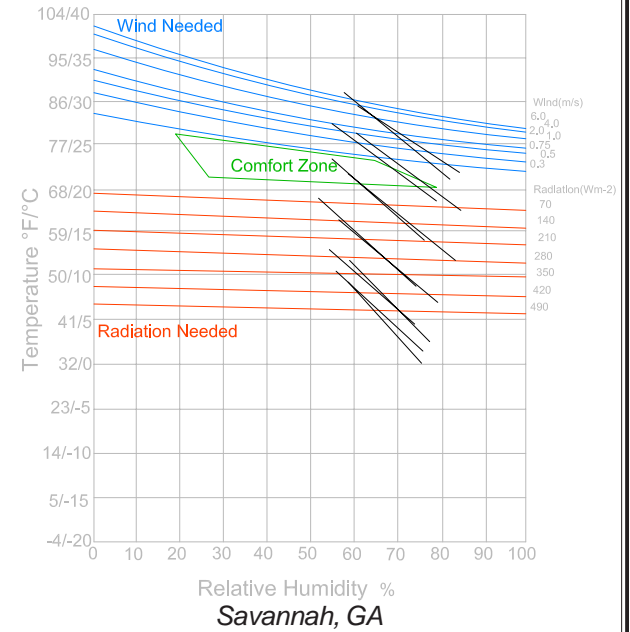
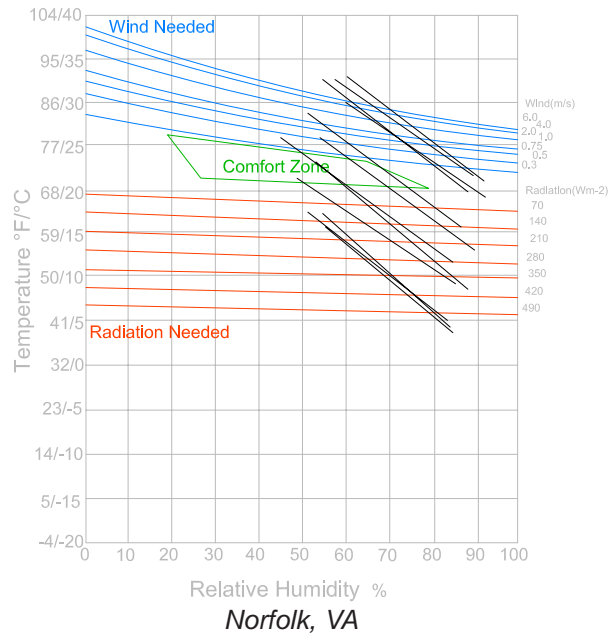
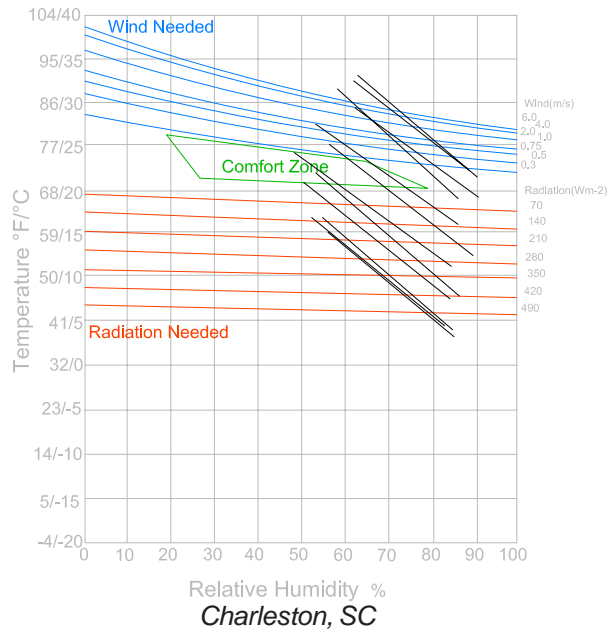
Five coastal cities were chosen in the Mid-Atlantic region of the United States to determine if and how well they include climatic design in their ordinances. The cities chosen include Charleston, South Carolina; Norfolk, Virginia; Savannah, Georgia; Washington, D.C.; and Wilmington, North Carolina. The mid-Atlantic cities' bioclimatic charts (Figure 4.4) illustrates that all five

cities look very similar with the exception of a few extreme temperatures. This indicates that the cities experience similar climatic situations and should have similar goals and requirements in their parking lot ordinances. It should be noted, however, that all cities have certain climatic characteristics specific to that individual city and those should be taken into account when creating parking lot ordinance requirements. A brief summary of the contents of the Mid-Atlantic parking lot ordinances are included in Table 4.2 followed by a visual summary in Figure 4.5.

With the exception of Washington, D.C., the Mid-Atlantic ordinances were similar in content to the case study ordinances reviewed in the last section. All five cities require a minimum amount of landscaping and none of them require a specified amount of shade. Perimeter screening standards for the Mid-Atlantic were also similar to the case study ordinances.

Washington, D.C. had the most inadequate parking lot ordinance in that it never mentions anything about a tree requirement in the parking lot ordinance. Requiring landscaping in the parking lot does not ensure that trees will be planted. If an ordinance is only going to require a specific amount of landscaping, then it becomes necessary to require a specific number of trees to be planted within that landscaping.

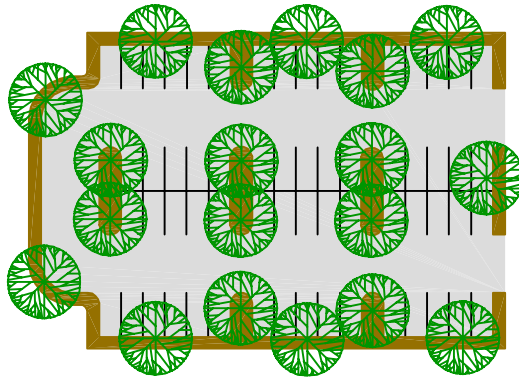
Planting standards and maintenance guidelines for the Mid-Atlantic cities were also very vague. Planting instructions for most cities are almost non-existent and the maintenance guidelines



**Figure 4.4. Mid-Atlantic Bioclimatic Charts. Adapted from Lynch & Hack, 1984.**

	<b>Ordinance Requirements</b>	<b>Charleston, SC</b>	<b>Norfolk, VA</b>	<b>Savannah, GA</b>	<b>Washington, DC</b>	<b>Wilmington, NC</b>
<b>Heat Mitigation</b>	landscaping	1 island per 7 parking spaces	10%		5%	8%
	shade					
	distance between islands	≤15 spaces	evenly dispersed	≤12 spaces		evenly dispersed
	# of trees	1 per island	1 per 144ft <sup>2</sup> of landscaping	1200 tree quality tree points per acre		1 per 144ft <sup>2</sup> of landscaping
	size of parking lot	regulates max. size				regulates max. size
	surface type	permits alternative paving	permits alternative paving	permits alternative paving	permits alternative paving	permits alternative paving
<b>Wind Mitigation</b>	perimeter screen height	3ft	2.5ft	3ft	42in	3ft
	perimeter trees	1 per 50ft	1 per 25ft			1 per 18-27ft
<b>Planting Standards</b>	island size	regulates min.	regulates min.	regulates min.		regulates min.
	island type		recommends clustered	recommends clustered		
	tree list provided	√	√	√		√
	tree size at planting	regulates min.	regulates min.	regulates min.		regulates min.
	planting instructions	meet current nursery standards	gives planting seasons			
	-info on soils		√			
	-info on drainage					
	-info on irrigation				√	
-info on mulching		√				
<b>Plant Maintenance</b>	growth management	maintain healthy, growing condition	maintain healthy, growing condition		maintain healthy, growing condition	maintain healthy, growing condition
	-pruning					
	-topping					
	-fertilization			required		
	damage management	protect from cars	protect from cars		protect from cars	protect from cars
insect & disease control						

Table 4.2. Matrix of Mid-Atlantic Parking Lot Ordinances.



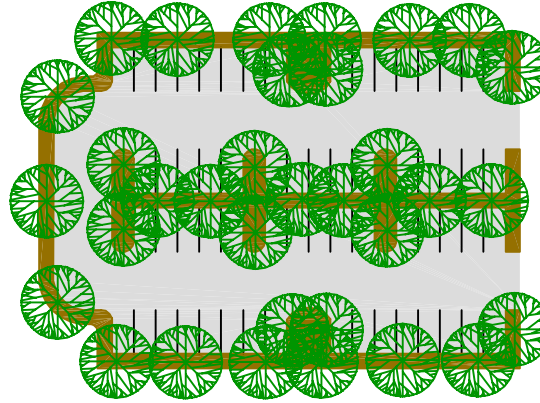
**Charleston, SC**

*Interior:*

- 1 island (9'X18') per 7 spaces
- 1 tree per island

*Perimeter:*

- screens at least 3' high
- 1 tree every 50'



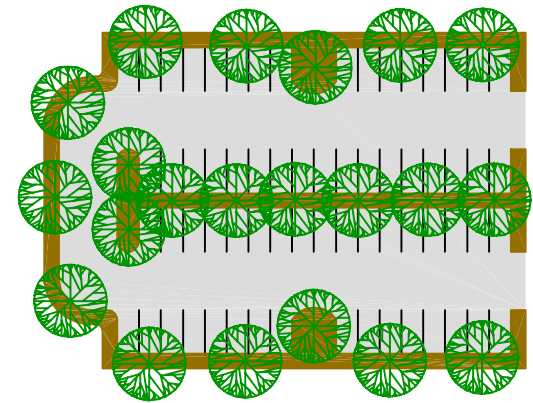
**Norfolk, VA**

*Interior:*

- 10% landscaping
- 1 tree per 144ft<sup>2</sup> of landscaping

*Perimeter:*

- screens at least 2.5' high
- 1 tree every 25'



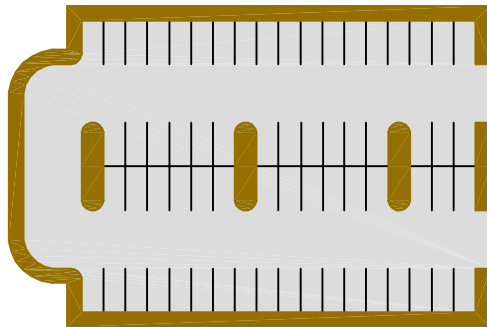
**Savannah, GA**

*Interior & Perimeter trees:*

- 1200 tree quality points per acre

*Perimeter screens:*

- at least 3' high



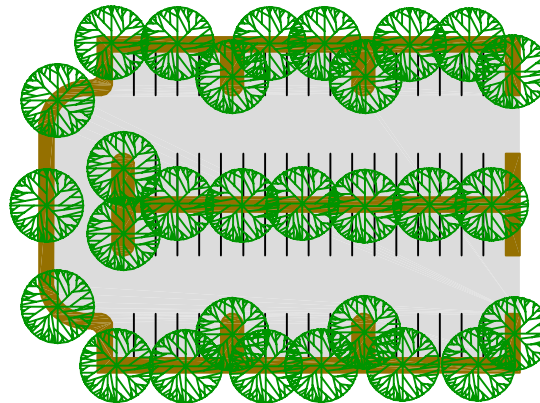
**Washington, DC**

*Interior:*

- 5% landscaping
- no requirement for trees

*Perimeter:*

- screens at least 42" high
- no requirement for trees



**Wilmington, NC**

*Interior:*

- 8% landscaping
- 1 tree per 144ft<sup>2</sup> of landscaping

*Perimeter:*

- screens at least 3' high
- 1 tree every 18'-27'

Figure 4.5. Illustration of Mid-Atlantic Parking Lot Ordinances. Plans showing minimum landscaping requirements for parking lot ordinances in the Mid-Atlantic region.

only require that plants remain in a healthy, growing condition and be protected from the encroachment of cars.

Table 4.3 ranks the requirements of the Mid-Atlantic ordinances based on the strongest and weakest requirements from the case study ordinances. This comparison shows that the requirements for the Mid-Atlantic ordinances falls well below the standards set by the best case study ordinances. In order to make a change in urban climate, cities need to write strong ordinance requirements across the board. Planting standards and maintenance guidelines should be given more attention in parking lot ordinances and should always be included.

None of the ordinances, case study or Mid-Atlantic, contained thorough information in all of the areas of designing with climate. Some lessons, however, can be taken from the positive aspects of these ordinances. For example, requiring a certain percentage of shade cover instead of a percent of vegetation. These positive techniques, along with principles learned from the literature review, will be used in the next section to create guidelines for writing a Mid-Atlantic parking lot ordinance.



*Figure 4.6. Existing parking lot in Charleston, SC showing current parking lot ordinance requirements.*

	<b>Most Strict (5)</b>	<b>Least Strict (1)</b>	<b>Charleston, SC</b>	<b>Norfolk, VA</b>	<b>Savannah, GA</b>	<b>Washington, DC</b>	<b>Wilmington, NC</b>
<b>Heat Mitigation</b>	Sacramento, CA – requirement of % shading will produce better results than a requirement of % landscaping	Lexington-Fayette, KY – 5% landscaping is not enough to make significant change – too few trees are required within the landscaping	3	2	1	0	2
<b>Wind Mitigation</b>	Portland, OR – requires solid (95% opaque) screen – requires perimeter trees	Lexington Fayette, KY – 6' tall screen is too high to admit summer breezes into the site	3	4	2	2	4
<b>Planting Standards</b>	Lexington-Fayette, KY – supplemental manual provides instructions and diagrams on proper urban planting standards	Fairfax, VA – does not require any information on planting	3	2	2	0	1
<b>Plant Maintenance</b>	Lexington-Fayette, KY – supplemental manual provides information on the care of urban plants	Fairfax, VA – contains little information on plant care	1	1	0	1	1

*Table 4.3. Comparative Parking Lot Ordinance Matrix. The matrix lists the most and least strict case study ordinances in the first two columns and gives a brief explanation of why that ordinance is the most or least strict. The five columns to the right list the Mid-Atlantic ordinances and rank their ordinances based on the most and least strict case study ordinances; most strict is ranked a five and least strict is ranked a one. For example, Norfolk's inclusion of heat mitigating principles in their ordinance ranks a two because its requirements are only slightly more strict than those of Lexington-Fayette. Washington, DC, however, receives a zero because they require less heat mitigating principles than Lexington-Fayette.*

## **Chapter 5: Mid-Atlantic Parking Lot Ordinance Guidelines**

This chapter discusses elements that should be included in every Mid-Atlantic parking lot ordinance. These elements were introduced by the literature review and case study ordinances and have been adapted to the climate of the Mid-Atlantic region. The climate of the Mid-Atlantic region of the United States can be classified as having hot, humid summers with milder winters. The cities chosen for this project have similar temperature ranges with the northern cities being slightly cooler than the southern cities. Winds for all cities generally prevail from the same direction and precipitation is common year round.



**Mid-Atlantic Climate:**

	<u>Washington, DC</u>	<u>Savannah, GA</u>
Average Jan. temp. range-	27°F to 43°F	38°F to 60°F
Average July temp. range-	70°F to 88°F	72°F to 92°F
Average days/year above 90°F-	37	69
Heating degree days-	4923	1766
Cooling degree days-	1075	2471
Average morning humidity-	83%	87%
Average afternoon humidity-	55%	54%
Average yearly rainfall-	42 inches	50 inches
Average yearly snowfall-	22 inches	0.5 inch
Average winter winds-	NW 10mph	W 9mph
Average summer winds-	S 9mph	S 7mph

Figure 5.1. Mid-Atlantic Context Maps. Annual climatic information has been provide for the most northern and southern cities with the remaining cities' climates falling somewhere in between.

Guidelines for Mid-Atlantic Parking Lot Ordinances

The following guidelines are based on principles for designing with climate and issues raised during the analysis of current U.S. and Mid-Atlantic parking lot ordinances. As shown by the Mid-Atlantic bioclimatic charts in the previous chapter, the climates of these cities are similar and, therefore, these cities can all use the same guidelines in writing their parking lot ordinances. These guidelines provide information that should be included in all Mid-Atlantic parking lot ordinances in order to help limit unwanted climatic elements. These guidelines pertain only to aspects of a parking lot ordinance that address climate amelioration and do not directly deal with other important issues such as safety or aesthetics. These guidelines have been divided into the four primary concerns for climate amelioration: heat mitigation, wind mitigation, planting standards, and plant maintenance.

*Heat Mitigation:* The major parking lot design decisions that have an effect on urban heat islands are parking lot size, surfacing, and shading.

*-Parking lot size:* Specifying maximum sizes for parking lots can help to prevent businesses from creating enormous lots that are greatly underutilized during most of the year. Both minimums and maximums should be developed based on the adequacy of the public transportation system and the

results of parking surveys for that specific city. In cities where there is an excellent public transportation system, it may be feasible to require less parking. Cities without public transit may need to require more spaces to service downtown business districts.

The parking needs of one city cannot be decided based on national parking demand surveys because each city will have different parking needs. Every city needs to survey its own parking needs to determine the amount of parking area needed to sustain local businesses. More accurate numbers will also be realized if the city conducts separate surveys for each individual district. Once minimum standards are created, maximums can be estimated based on the capacity of local street systems.

*-Alternative surfacing:* One of the easiest ways to regulate surfaces may be to require a range of surface albedos that parking lots must be paved with. This range can restrict developers from using dark surface material while still leaving them with choices.

Ordinances should also allow for and encourage the use of alternative paving materials in parking lots. Lots that are infrequently used (churches, sports stadiums, etc.) could have much more strict regulations that require porous or unimproved surfaces. Cities may wish to require overflow lots to remain grass or be paved with grass pavers.

Reductions in other requirements, such as landscaping, could be given to lot owners as an incentive for using alternative paving materials.

*-Shading parking areas:* In order to make a noticeable difference in urban heat islands, a large percentage of shading needs to be required for each parking lot. American Forests (n.d.) recommends that an average of 40% canopy cover needs to exist in urban areas. Much of this canopy cover demand needs to be met in open spaces and parking lots as they provide the most reasonable spaces. It is suggested here that at least 50% shading be required in all parking lots.

The shading requirement should be met within an acceptable time span depending on the types of trees that are planted in the lot. Grouped trees should be recommended to provide better shade, but it should be required that shade be spread evenly throughout the lot.

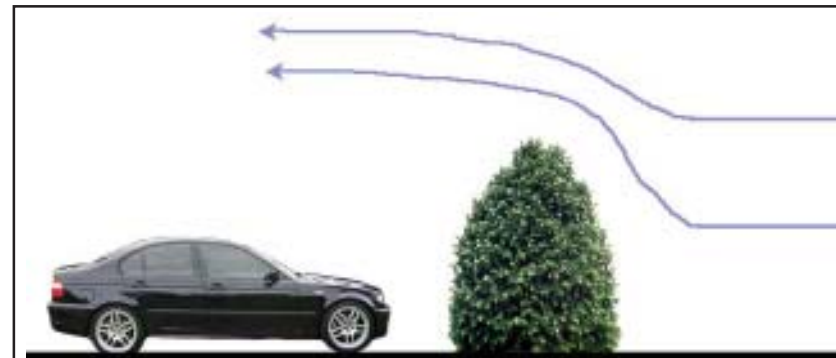
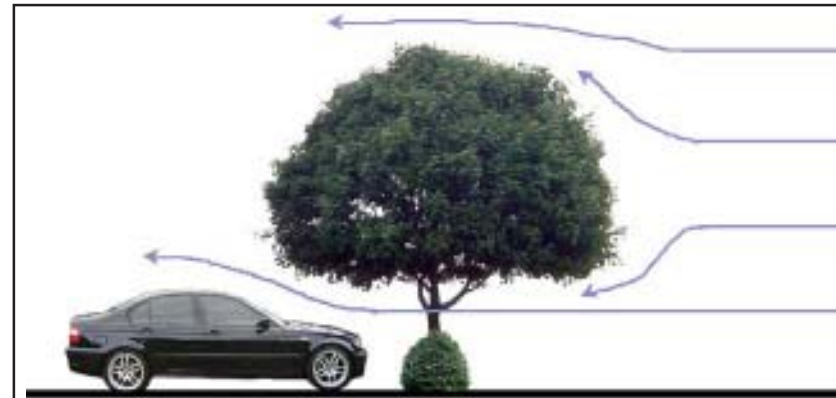
Cities should require the submittal and approval of shade plans along with other construction drawings before permits are issued. Instructions, preferably in the form of a supplemental manual, should be provided to illustrate how to calculate shade and providing examples would be beneficial. Manuals also need to include tree lists of species that are capable of providing sufficient shade, withstanding the harsh environment of parking lots, and cause little mess. Cities could use Sacramento's manual (Appendix B) as a

guide to writing their own supplemental manual.

*Wind Mitigation:* The use of perimeter and interior landscaping will be used to manage wind movement through the site.

*-Perimeter landscaping:* It is not recommended that Mid-Atlantic cities require tall, solid screens around the perimeter of parking lots even in the case of different adjacent uses. The high humidity levels in the Mid-Atlantic region make winds a necessary element during warm periods, especially in hot spaces such as parking lots. Tall screens restrict this airflow creating stagnant spaces. For this reason, it is recommended that only low screens (three feet tall) should be required for perimeter landscaping. Low hedges are capable of providing the necessary screens for safety purposes as well as providing separation between adjoining uses. Trees can be used in conjunction with the low hedge if more of a visual barrier is required. The line of trees will also help to slow wind through the site while still leaving space between the shrubs and the bottom of the tree canopy for air circulation. Figure 5.2 illustrates different vegetation patterns that could be used along parking lot perimeters to manage wind.

If winter winds are a severe problem for particular parking lots, taller screens could be used on a case-by-case basis. In the Mid-Atlantic region, winter winds generally prevail from a northwesterly direction while summer winds come from



*Figure 5.2. Typical Wind Patterns. The combination of trees and shrubs will allow some wind to enter the parking lot (top). The use of large shrubs will restrict airflow into the parking lot (bottom).*

the southwest. Taller screens could be used on the northern perimeter of the site to obstruct winter winds leaving the southern end open to summer winds. A negative aspect of this design is that the tall screen can also prevent summer winds from moving into adjoining lots. Plan approval should also be required in this circumstance before construction

permits are obtained.

*-Interior landscaping:* Along with the shade trees required for heat mitigation, shrubs and ground covers should be required to fill islands. Understory evergreen shrubs throughout the parking lot will slow winds through the site. Shrubs should be kept to a height of approximately three feet, to still allow summer breezes to filter through. A height of three feet, as was the average height required by the case study ordinances, appears to be an appropriate height for several reasons. First, the lower height of the shrubs will allow winds to filter through the site (See Figure 5.2). The second reason is that three feet is tall enough to be prevent most headlights from leaving the parking lot and creating a nuisance.

*Planting Standards:* Appendix A discusses important planting standards for urban vegetation. Planting standards for parking lot vegetation should be provided in a supplemental manual so as not to clutter the parking lot ordinance. The following is a minimum amount of information that should be provided in the manual:

*-Tree list:* The tree list should include trees that are capable of providing dense shade, are tolerant of urban environments (high temperatures, pollution levels, etc.), are pest and disease resistant, and require little maintenance. It may also be helpful to provide a list of shrubs and ground covers that are acceptable for parking lot landscaping. There should also be a list of vegetation prohibited for use in parking lots, such

as trees with messy fruits or invasive roots.

*-Planting season:* Allowances should be made for the timely planting of vegetation in parking lots. Planting should generally be done in either the fall or spring, but some species may transplant better during other times of the year. The ordinance should allow parking lots to go unplanted until the proper transplant time to ensure higher survival rates.

*-Island size:* The size of the islands used in parking areas will greatly depend on the amount and type of vegetation that is planted in those islands. Ordinances should recommend clustered planting areas or planting strips. Minimum island sizes should be contingent on the number and type of trees planted in each island. The tree list could specify minimum island sizes for specific tree species based on canopy size. The recommended suggestion is two cubic feet of soil for every square foot of tree canopy for adequate growth (Lindsey & Bassuk, 1991).

*-Soils:* Soils should be tested for nutrients, minerals, and drainability. Soils that do not meet minimum requirements should be replaced with well-balanced soils. The manual could recommend the use of structural soils and educate developers on the benefits of using such soils.

*-Aeration:* If soils are too compacted to “breathe” then they should be replaced with less compacted, well drained soils.

*-Drainage:* All landscaped islands should be provided with a

means of draining excessive water, especially in stormwater filter strips.

*-Irrigation:* All landscaped islands should have irrigation systems installed for at least the first two years. Mulching should be required to assist the irrigation system.

*Plant Maintenance:* General maintenance that should be mentioned in the parking lot landscape ordinance include: weeding, remulching, replacement of dead or damaged materials, and any other practice that will ensure the health of the plant. Other maintenance elements that will require more instruction include: pruning, fertilizing, and pest and disease control.

*-Pruning:* Topping trees should be prohibited. All pruning should be administered in accordance with standard horticultural practices and should be administered by someone with experience.

*-Fertilizing:* Fertilizer should only be applied as needed according to soil testing and should never be applied within the first two years.

*-Pest and disease control:* Requiring that trees from the tree list be used in parking lots should minimize this problem. Problems that do occur should be treated appropriately as needed.

Once the parking lot ordinance has been created from these

guidelines, it must be enforced in order to reach its goals. The first step will be to make sure that parking lots are installed exactly as they are depicted on the approved plans. Once those parking lots are in use, cities will need to monitor them regularly to ensure that plants remain healthy and functional. Fines should be issued to those who do not maintain their parking lots.

Educating the public of the benefits of designing with climate may be the easiest way to ensure that parking lot ordinances are followed. Climate mitigation should be included in the statement of purpose followed by a brief section describing some of the benefits of designing with climate. This could include such things as economic savings for neighboring buildings as their heating and cooling loads will be reduced. An educational approach may be sufficient in convincing parking lot owners in the downtown business district to comply with ordinance regulations.



*Figure 5.3. Example Parking Lot in Norfolk, VA. This existing municipal parking lot illustrates the need for the regulation and enforcement of ordinance requirements.*

## **Chapter 6: Illustrative Design**

The parking lot ordinance guidelines from the previous chapter have been incorporated into two parking lot designs to illustrate their effect on the climate of the parking lot and surrounding areas. The site for the illustrative designs is located in Norfolk, Virginia. The site is first analyzed to determine its specific climatic needs and those results are then used in conjunction with the parking lot ordinance guidelines to produce a more climatically comfortable pedestrian space. Process drawings are provided to show how the new parking lot designs will effect and help to mitigate climate.

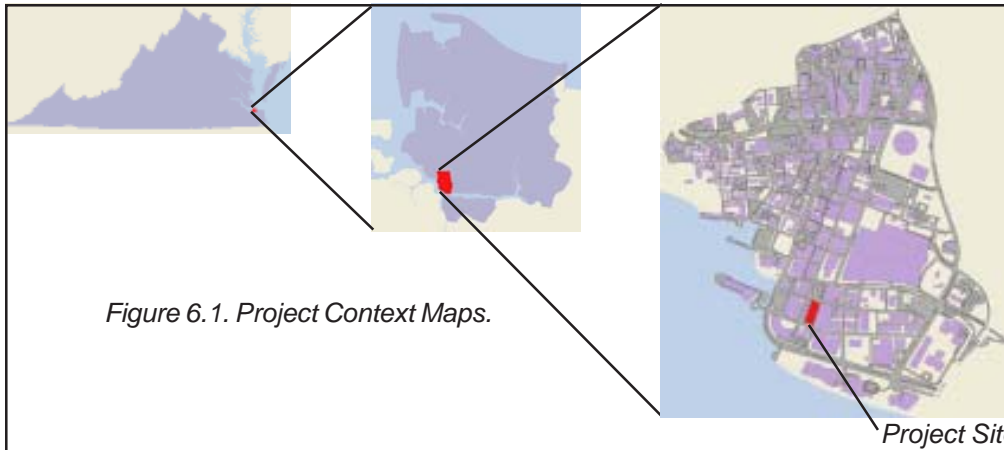


Figure 6.1. Project Context Maps.

**Norfolk Climate:**

Average January temperatures-	32°F to 48°F
Average July temperatures-	71°F to 87°F
Average days/year above 90°F-	33
Heating degree days-	3342
Cooling degree days-	1630
Average morning humidity-	78%
Average afternoon humidity-	57%
Average yearly rainfall-	46 inches
Average yearly snowfall-	8 inches
Average winter winds-	prevail from north
Average summer winds-	prevail from southwest
Average yearly wind speeds-	11mph

Project Site

Project Site

Norfolk, VA is a coastal city located towards the middle of the Mid-Atlantic area studied in this thesis. The chosen site is located in the downtown business district and is only a few blocks from one of the three large rivers that surround the city. The site is currently used as a privately owned parking lot and is approximately 38,000 square feet holding 56 parking spaces. The site has buildings along its east and west sides and streets along the north and south. It is currently paved with black asphalt and has only a few small planting areas containing small trees.



Figure 6.2. Existing Conditions of Project Site.

### Site Analysis

Shadow studies were created for the site during summer and winter seasons to determine the amount of solar radiation the lot receives throughout the year. Figures 6.3 - 6.6 show that the site receives full sun during the most intense hours of the day. Without receiving any shade from surrounding buildings during the summer, the parking lot will collect and store large amounts of heat during the summer creating uncomfortable situations for pedestrians. Winter sunlight for the site also proves to be problematic as there are only a few hours of the day that receive direct sunlight. With so little solar warmth reaching the parking lot during the winter, it is important to try and reduce chilling winds.

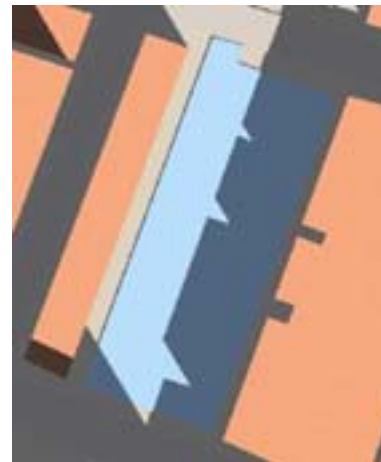
As discussed earlier, wind patterns will be difficult to predict without wind tunnel testing, but for the purpose of this project a few general assumptions have been made about wind movement through the site. Winter winds in Norfolk prevail from the north and summer winds prevail from the southwest. With the north and south ends of the parking lot being open to streets, wind will gust through the site with little or no obstruction. There are also water bodies within a few blocks to the west and south of the site which can lead to thermal breezes throughout the year.



*Figure 6.3. Shadow patterns for June 21 - 10am.*



*Figure 6.4. Shadow patterns for June 21 - 3pm.*



*Figure 6.5. Shadow patterns for December 21 - 10am.*



*Figure 6.6. Shadow patterns for December 21 - 3pm.*

### Illustrative Designs

Both designs for the site illustrate different ways in which to incorporate the ordinance requirements. The parking lot ordinance guideline requirements from chapter five have been met in both designs although the overall objective of each design is different.

#### *Design One:*

The goal of the first design was to create a parking lot for the pedestrian providing safety and a sense of belonging. The following are key elements of the design:

- Curved, narrow driving isles slow the speed of motorists.
- Central, raised sidewalk through the site creates safe pathway for pedestrians and speed bumps for motorists.
- Tree canopies bring the scale of the large site to the pedestrian



*Figure 6.7. Design One Perspective. Clustered trees provide plenty of shade for the parking lot as well as bringing the scale of the lot to the pedestrian level.*



*Figure 6.8. Design One.*

level.

- Landscaping strips are used instead of individual tree pits to provide more growing room for trees.
- Shrubs along the perimeter are used to block the nuisance of headlights blinding street traffic.
- Large planting beds in the center and along the perimeter of the parking lot are used to filter stormwater.
- Prevailing northern winter winds will be slowed by the shrubs on the north end of the site as well as the trees. The lack of shrubs on the southern end of the site will allow prevailing summer winds to cool the site.
- A variety of trees planted throughout the site provide at least a 50% shade cover for the parking lot.
- Paving for the site is a light-colored porous pavement that will help to filter stormwater and reduce this parking lot's impact on the city's stormwater system. The large amount of trees on the site will also help to intercept much of the rain water falling on the site.

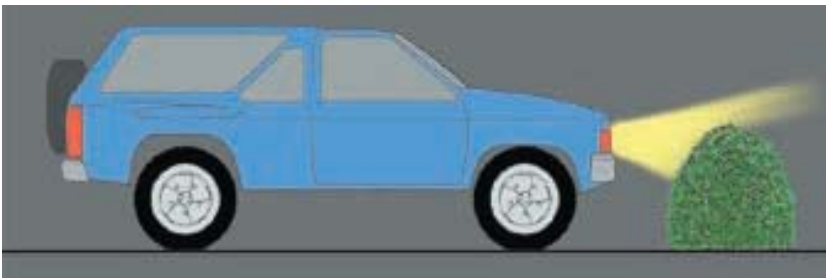


Figure 6.9. Headlight Block - Design One. Shrubs planted along the perimeter of the site help to block hazardous headlights.

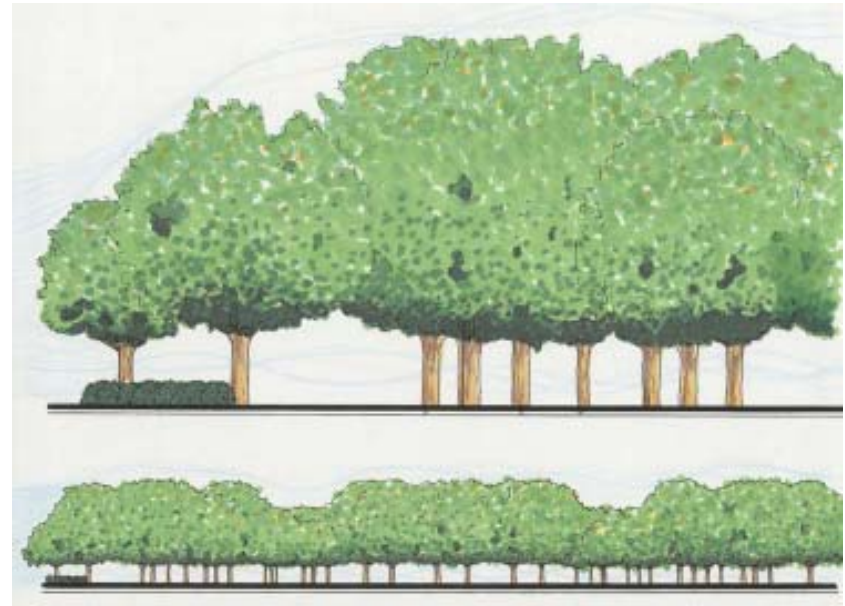


Figure 6.10. Wind Breaks - Design One. Tree branches will help to slow gusting winter winds while summer breezes will still be allowed into the site under the tree canopies.

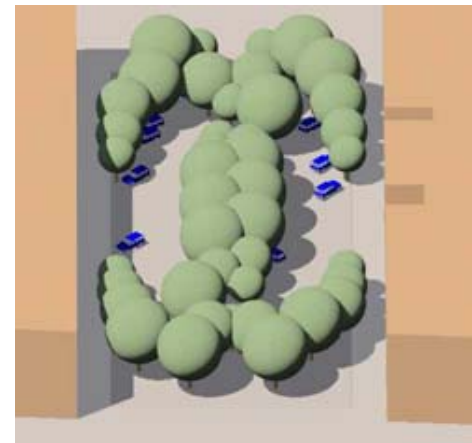
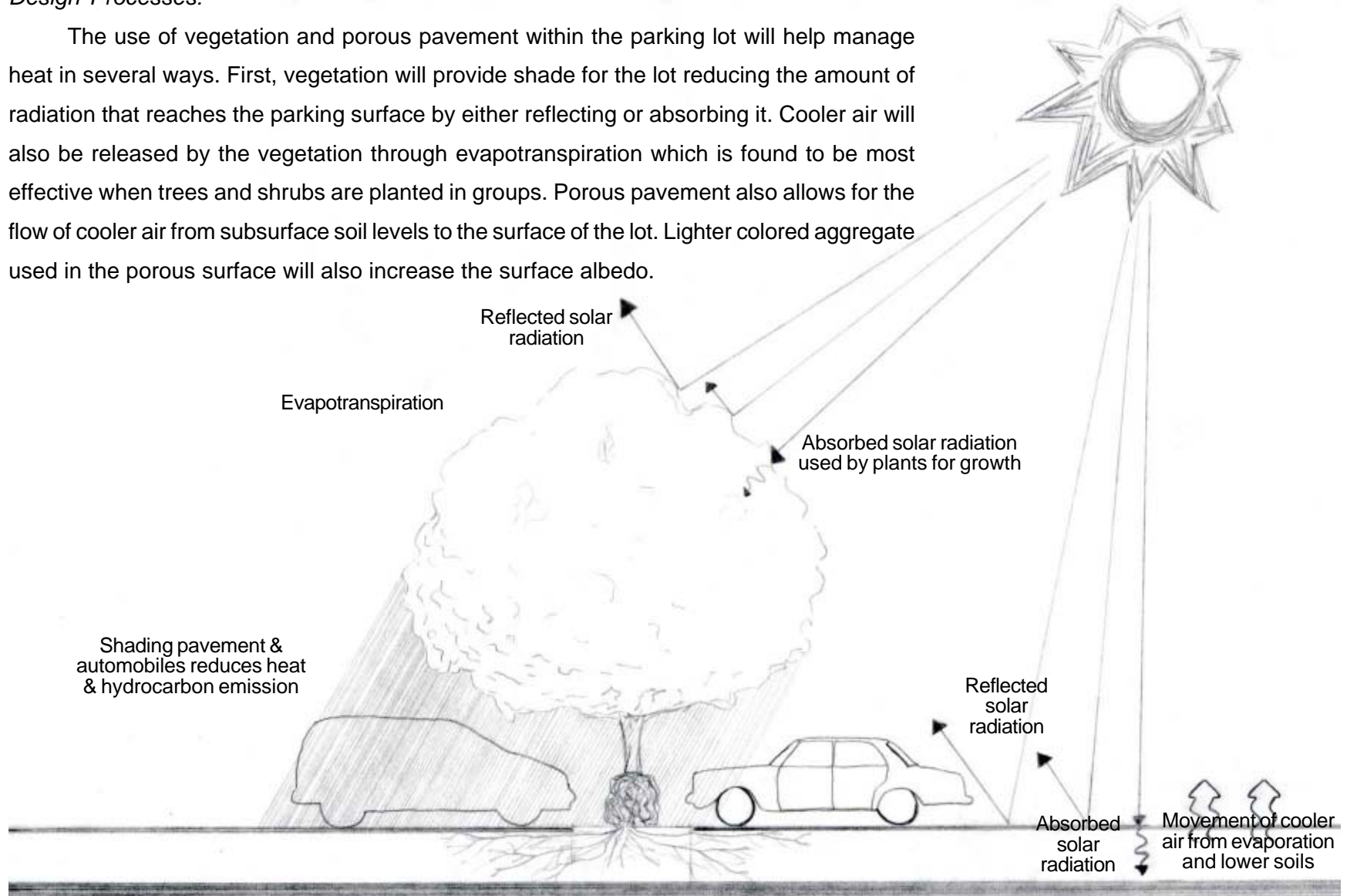


Figure 6.11. Shadow Study - Design One. Shadow patterns calculated for August 8th at 2:00 p.m.

*Design Processes:*

The use of vegetation and porous pavement within the parking lot will help manage heat in several ways. First, vegetation will provide shade for the lot reducing the amount of radiation that reaches the parking surface by either reflecting or absorbing it. Cooler air will also be released by the vegetation through evapotranspiration which is found to be most effective when trees and shrubs are planted in groups. Porous pavement also allows for the flow of cooler air from subsurface soil levels to the surface of the lot. Lighter colored aggregate used in the porous surface will also increase the surface albedo.



*Figure 6.12. Solar Radiation in the Parking Lot. The use of vegetation and lighter porous pavements in the parking lot will reduce the amount of heat stored in the parking lot. Porous pavements will allow the cooler subsurface air to move into the parking lot.*

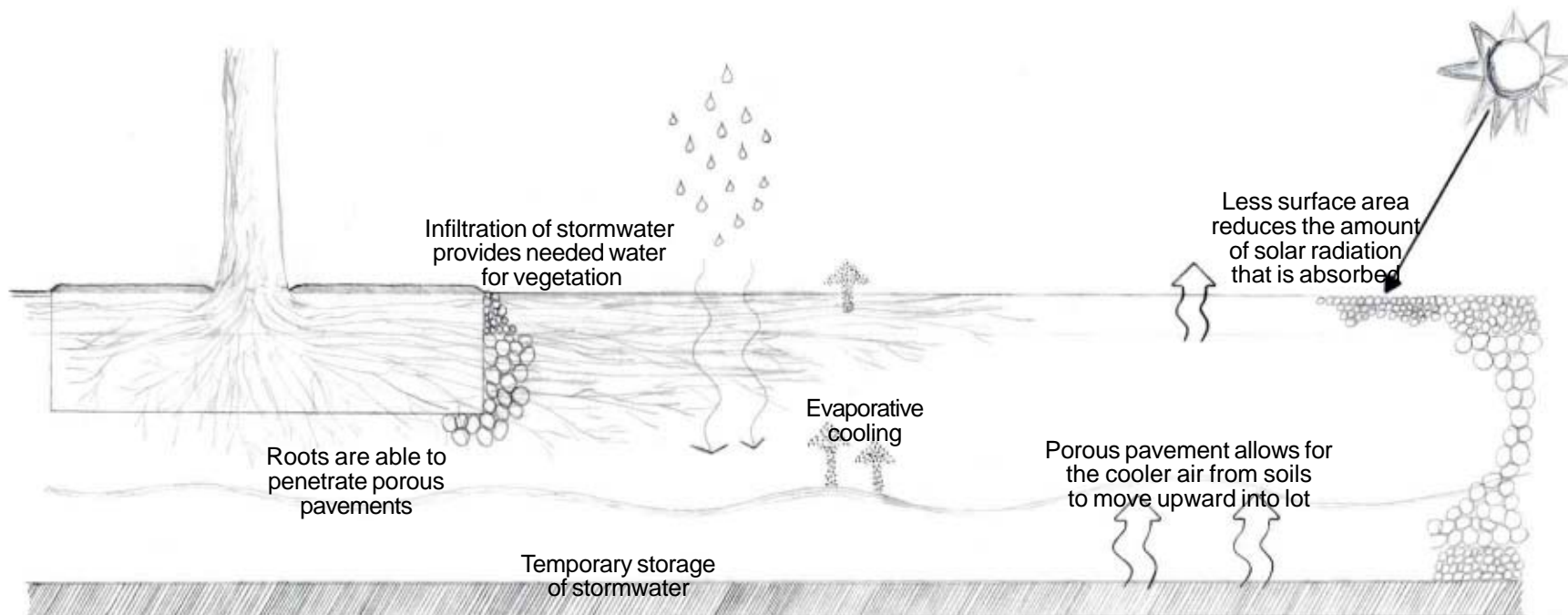


Figure 6.13. Porous Pavement in the Parking Lot. Porous pavements allow for the transfer of air and water through its surface which is beneficial to climate control and plant growth. Larger aggregate materials reduce surface area, decreasing the absorption of solar radiation.

Porous pavement is used in the site to reduce the amount of stormwater pumped into local stormwater systems. Stormwater filtered and then stored beneath the surface of the pavement. This water can then be taken up by the roots of local vegetation and used for growth. Water not used by plants will then begin to evaporate up through the pavement, using heat energy in the process and cooling the air just above the surface of the lot.

Using structural soils along with porous pavement will further enhance root growth and tree survival rate. With structural soils,

the tree roots will be able to easily manipulate their way through the soil beneath the parking lot to access the stormwater. Structural soils will also help to prevent damage to the parking lot surface by reducing buckling.

Porous pavements also use larger aggregates in the surface layer than do traditional asphalt pavements. The large aggregates diminish the amount of surface area capable of absorbing solar radiation.

The use of a combination of large shade trees with underlying shrubs will benefit the parking lot by allowing wind to pass through the site. Allowing winds to pass through the site during the summer will help to cool the lot by allowing cooler air into the lot. As heat rises from the surface of the parking lot, the wind will carry the heat away from the site eliminating stagnant hot air above the parking lot surface.

Large amounts of trees planted in the parking lot will also help to ameliorate winter winds. Even the bare branches of deciduous trees in the winter will cause drag and slow wind speeds.

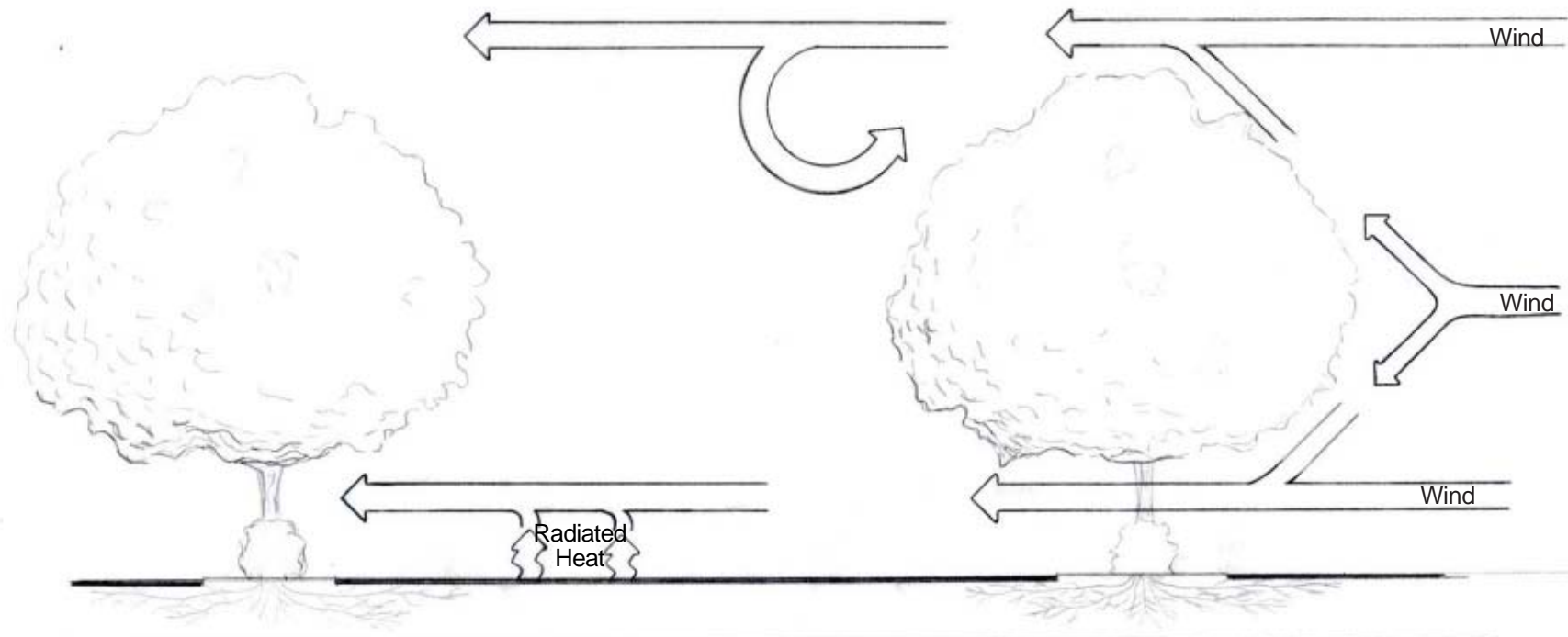
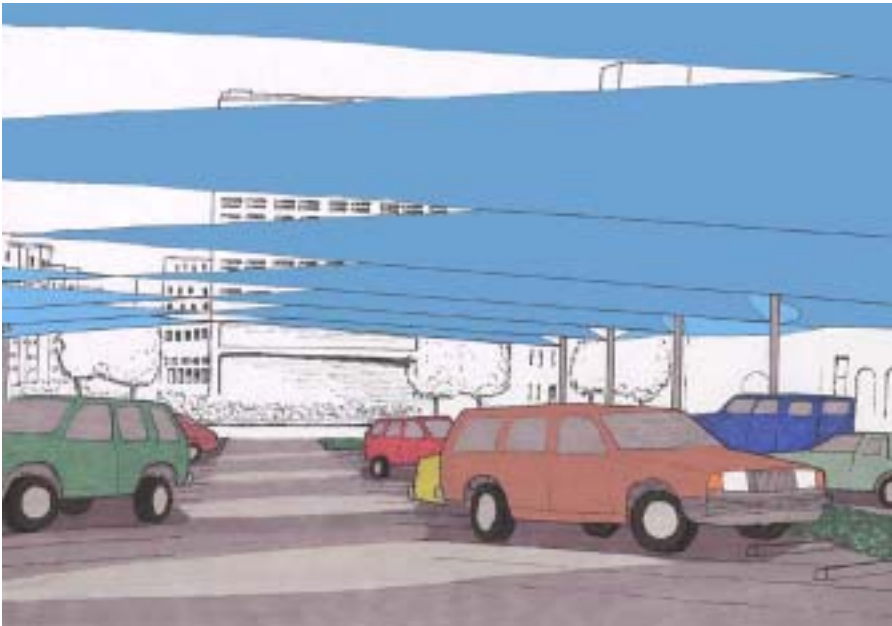


Figure 6.14. Wind in the Parking Lot. Any radiated heat from the surface of the parking lot will be carried off the site by wind. Leaving space between tree canopies and underlying shrubs allows wind to move through the site.

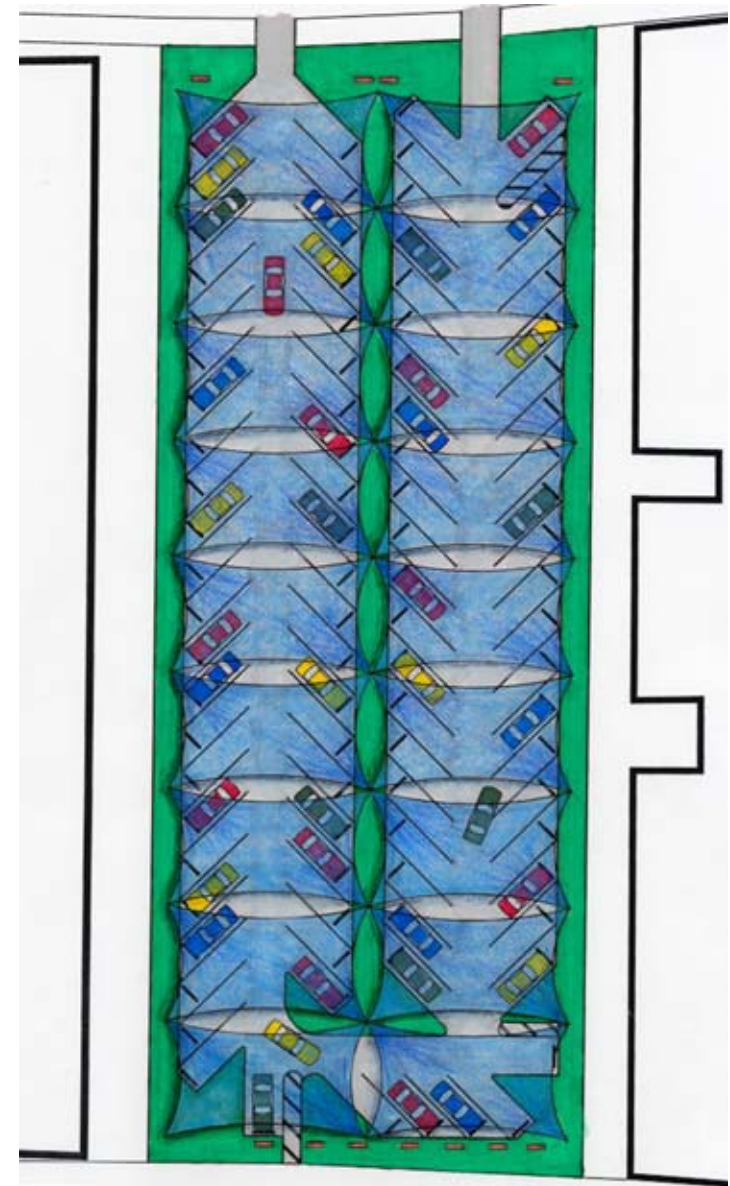
*Design Two:*

The design for the second site was meant to provide a parking lot that could hold as many parking spaces as possible; a common goal of many parking lot owners. This design illustrates that it is possible to create a parking lot with maximum parking spaces while still incorporating the elements of designing with climate. These are the key elements of the second design:

- Angled parking allows this narrow lot to hold its maximum number of cars.
- Shade sails are used to cover the entire paved area providing



*Figure 6.15. Design Two Perspective. Design Two creates a maximum amount of shade for the parking lot while still allowing for the maximum number of parking spaces.*



*Figure 6.16. Design Two.*

well over the recommended 50% shade. These shade sails can also help to slow the rate of stormwater entering the site.

- Grass areas along the edge of the paved areas are used to hold and filter stormwater falling on the site.
- Benches are use at both ends of the site to provide some buffer for winds. The shade sails will also help to obstruct and slow winds.
- Benches are also used to help diffuse headlights from within the parking lot.

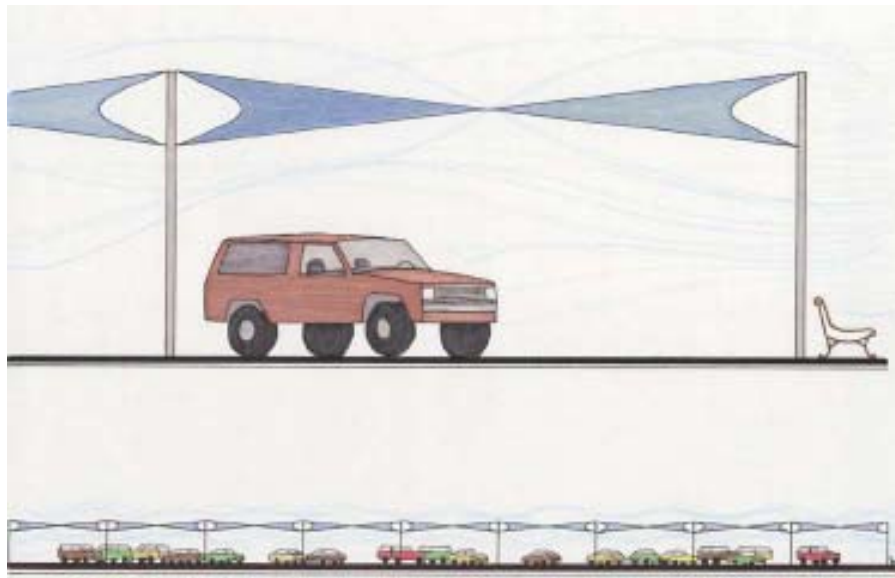


Figure 6.17. Wind Breaks - Design Two. Leaving the shade sails up year-round will help to create drag slowing the velocity of winter winds. Cars parked in the lot will also help to slow winds.

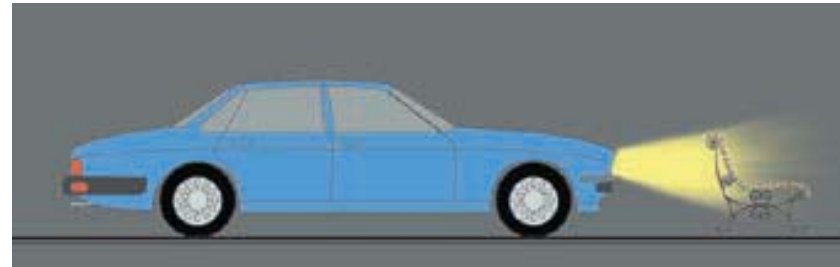


Figure 6.18. Headlight Block - Design Two. Benches placed in front of parking spaces will help to diffuse headlights.

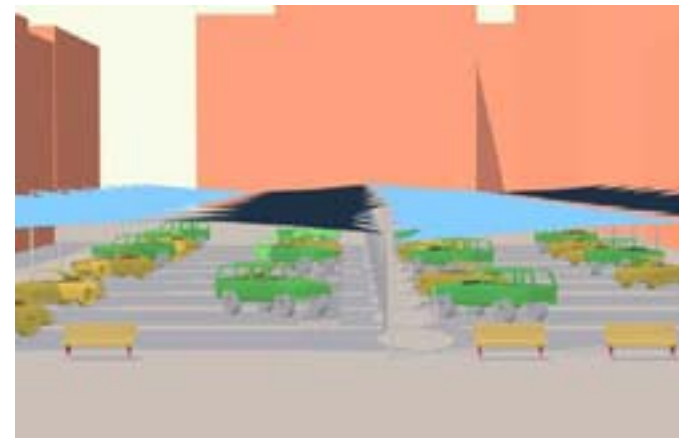


Figure 6.19. Shadow Study - Design Two. Shadow patterns calculated for August 8th at 2 p.m.

The design of a parking lot can have a dramatic effect on a city's climate. Good designs can improve the climate, making it more comfortable for humans; bad designs can aggravate existing climatic problems, making pedestrians much less comfortable. The parking lot design guidelines given in the previous chapter will begin to improve climate in the Mid-Atlantic region if implemented properly. Since every site is unique, the principles will need to be incorporated in a manner suitable for each site. A site analysis of climatic needs will help to inform the designer on how to incorporate these principles. Only through a combination of all the design principles will the climatic results be realized.

## **Chapter 7: Major Findings and Conclusions**

The climate of the city is not only affected by local weather patterns, but also by the built form of the city. Failure to take climate into consideration when designing the city may lead to higher air pollution, poor water quality, higher energy consumption, and poor human health. Landscape architects have the ability to lessen these effects by designing with climate. All that is needed to accomplish this task is a working knowledge of climatic processes and the affect urban form has on those processes.

Three common phenomena occur in every city: urban heat island, urban wind, and urban precipitation. These phenomena

are the direct result of the built form of the city. Gross amounts of impervious surface area and the lack of vegetation contribute to making the urban climate different from its rural counterpart. Impervious surfaces lead to heat buildup within the city and the lack of vegetation causes the city to lose out on natural cooling processes that are present in rural areas.

Landscape architects can use design to decrease impervious surface areas and increase vegetation throughout the city. Vegetation, especially in the form of shading species, can be used throughout the city to limit the amount of impervious area susceptible to heat gain. Alternative surfaces with higher albedos could be used to lower heat storage within the city. Strategically placing vegetation along streets and in open spaces in the city can help to minimize gusting winds. Urban open spaces provide great potential for landscape architects to use principles of designing with climate.

Parking lots are one of the most abundant open spaces found in urban areas, yet little thought is given to their design. Parking lots can constitute over one-third of the impervious surface area of cities, contributing greatly to urban heat build-up. The redesign of all parking lots in a single city to comply with climatic design standards will dramatically improve the state of that city's urban climate. Parking lot ordinances can be used to facilitate this change.

This thesis found that current parking lot ordinances in

several cities throughout the United States are inadequate in terms of designing with climate. Ordinances from different climatic regions of the country have almost identical ordinance requirements indicating that those ordinances are not responding to their local climate. Different climatic regions should have region specific climatic objectives in their ordinances. This thesis did find, however, that within the same climatic region it is possible for cities to have very similar ordinances mainly because the climatic needs of the region will be the same throughout.

Unhealthy, dying vegetation is one of the primary reasons that most parking lot ordinances do not have an impact on local climate. Parking lots provide a very harsh environment in which plants are expected to survive. For this reason, vegetation within the lot has special needs in terms of planting and maintenance. Instructions for proper planting standards and plant maintenance need to be provided as part of the parking lot ordinance in order to ensure the plant's survival. If the vegetation does not survive, there is no chance that the climatic goals of the parking lot will be met.

This thesis is based primarily on the results of other urban climate studies. Further research needs to be done to determine the effectiveness of the principles discussed here. These studies would include:

- wind testing to determine the ability of specific trees and shrubs to block/reduce wind speeds
- using methods other than computer modeling to determine

the effect higher albedos have on mesoclimate.

-determining the extent to which evaporative cooling and evapotranspiration can have on parking lot temperatures.

Understanding the basic processes of climate and the principles of designing with climate will provide the landscape architect with the knowledge to create a set of design principles for any open space. Designing with climate will help to eliminate a city's climate problems while creating a cleaner, healthier environment for its inhabitants.

## Chapter 8: References Cited

Akbari, H., S. Davis, J. Huang, P. Liu, & H. Taha (1992). The Urban Heat Island: Causes and Impacts. In Akbari, H., S. Davis, S. Dorsano, J. Huang, & S. Winnett (Eds.), *Cooling our Communities: A Guidebook on Tree Planting and Light-Colored Surfacing* (LBL-31587) (5-26). United States Environmental Protection Agency and Lawrence Berkeley Laboratory.

Akbari, H., P. Martien, & A. Rosenfeld (1992). Using Light-Colored Surfaces to Cool Our Communities. In Akbari, H., S. Davis, S. Dorsano, J. Huang, & S. Winnett (Eds.), *Cooling our Communities: A Guidebook on Tree Planting and Light-Colored Surfacing* (LBL-31587) (43-52). United States Environmental Protection Agency and Lawrence Berkeley Laboratory.

American Forests (n.d.). What is the National Urban Tree Deficit and Why Do We Care? Retrieved March 30, 2004, from <http://www.americanforests.org/graytogreen/treedeficit/>

American National Standards Institute (1998). *American National Standard for Tree Care Operations - Tree, Shrub, and Other Woody Plant Maintenance - Standard Practices (Fertilization)* (A300, Part 2). New York, NY: ANSI.

American National Standards Institute (2001). *American National Standard for Tree Care Operations - Tree, Shrub, and Other Woody Plant Maintenance - Standard Practices (Pruning)* (A300, Part 1). New York, NY: ANSI.

Asaeda, T., V.T. Ca, & A. Wake (1996). Heat Storage of Pavement and its Effect on the Lower Atmosphere. *Atmospheric Environment*, 30 (3), 413-427.

ASHRAE (1992). *Thermal Environmental Conditions for Human Occupancy*. ANSI/American Society of Heating, Refrigerating, and Air-Conditioning Engineers Standard 55-1992.

Bassuk, N., J. Grabosky, P. Trowbridge, J. Urban (1998). *Structural Soil: An Innovative Medium Under Pavement That Improves Street Tree Vigor*. ASLA Annual Meeting Proceedings; 183-185.

Bosselmann, P. (1998). *Representation of Places: Reality and Realism in City Design*. Berkeley: University of California Press.

Brown, R.D. (1982). *Application of Human Thermal Comfort to Landscape Architecture: A New Approach*. MLA thesis, University of Guelph.

Childs, M.C. (1999). *Parking Spaces: A Design, Implementation, and Use Manual for Architects, Planners, and Engineers*. New York: McGraw Hill.

City of Charleston, South Carolina (2003). *City of Charleston Code of Ordinances*. Retrieved February 4, 2004, from the Municode.com Web site: <http://www.municode.com/>

City of Fairfax, Virginia (2003). *City of Fairfax Code of Ordinances*. Retrieved February 4, 2004, from the Municode.com Web site: <http://www.municode.com/>

City of Norfolk, Virginia (2003). *City of Norfolk Code of Ordinances*. Retrieved February 4, 2004, from the Municode.com Web site: <http://www.municode.com/>

City of Orlando, Florida (2003). *City of Orlando Code of Ordinances*. Retrieved February 4, 2004, from the Municode.com Web site: <http://www.municode.com/>

City of Portland, Oregon (2003). *City of Portland Code of Ordinances*. Retrieved February 4, 2004, from the City or Portland Web site: <http://www.portlandonline.com/auditor/index.cfm?c=26653>

City of Sacramento, California (2003). *Parking Lot Tree Shading Design and Maintenance Guidelines*. Retrieved February 4, 2004, from the City of Sacramento Web site: [http://www.cityofsacramento.org/planning/longrange/SHADING\\_GUIDELINES\\_06-05-03.pdf](http://www.cityofsacramento.org/planning/longrange/SHADING_GUIDELINES_06-05-03.pdf)

City of Savannah, Georgia (2003). *City of Savannah Code of Ordinances*. Retrieved February 4, 2004, from the Municode.com Web site: <http://www.municode.com/>

City of Washington, D.C. (2003). *District of Columbia Code of Ordinances*. Retrieved February 4, 2004, from the District of Columbia Web site: <http://www.rrc.dc.gov/gov/site/default.asp>

City of Wilmington, North Carolina (2003). *City of Wilmington Code of Ordinances*. Retrieved February 4, 2004, from the Municode.com Web site: <http://www.municode.com/>

Cool, R.A. (1978, November). Tree Planting, Moving, and Aftercare. *Proceedings of the National Urban Forestry Conference*, Washington, DC, 2, 551-558.

Corwin, M.A. (1978). *Parking Lot Landscaping* (Planning Advisory Service Report No. 335). Chicago, IL: American Society of Planning Officials.

County of Lexington-Fayette, Kentucky (2003). *Lexington-Fayette Code of Ordinances*. Retrieved February 4, 2004, from the Municode.com Web site: <http://www.municode.com/>

Davis, S., P. Martien, N. Sampson (1992). Planting and Light-Colored Surfacing for Energy Conservation. In Akbari, H., S. Davis, S. Dorsano, J. Huang, & S. Winnett (Eds.), *Cooling our Communities: A Guidebook on Tree Planting and Light-Colored Surfacing* (LBL-31587) (93-110). United States Environmental Protection Agency and Lawrence Berkeley Laboratory.

Day, S., N. Bassuk, & H. van Es (1995). Effects of Four Compaction Remediation Methods for Landscape Trees on Soil Aeration, Mechanical Impedance and Tree Establishment. *Journal of Environmental Horticulture*, 13 (2), 64-71.

Givoni, B. (1963). *Estimation of the Effect of Climate on Man: Development of a New Thermal Index*. Haifa, Israel: Building Research Station, Technion-Israel Institute of Technology.

Golany, G.S. (1996). Urban Design Morphology and Thermal Performance. *Atmospheric Environment*, 30 (3), 455-465.

Grabosky, J., M. Bassuk, P. Trowbridge (2002). Structural Soils: A New Medium to Allow Urban Trees to Grow in Pavement. Landscape Architecture Technical Information Series; ASLA.

Grey, G.W. & F.J. Deneke (1986). *Urban Forestry* (2<sup>nd</sup> ed.). New York, NY: John Wiley and Sons.

Harris, R.W., J.R. Clark, & N.P. Matheny (1999). *Arboriculture: Integrated Management of Landscape Trees, Shrubs, and Vines* (3<sup>rd</sup> ed.). Upper Saddle River, NJ: Prentice Hall.

Heisler, G.M. (1986). Energy Savings with Trees. *Journal of Arboriculture*, 12 (5), 113-125.

Huang, J., R. Ritschard, N. Sampson, H. Taha (1992). The Benefits of Urban Trees. In Akbari, H., S. Davis, S. Dorsano, J. Huang, & S. Winnett (Eds.), *Cooling our Communities: A Guidebook on Tree Planting and Light-Colored Surfacing* (LBL-31587) (27-42). United States Environmental Protection Agency and Lawrence Berkeley Laboratory.

Landsberg, H.E. (1981) *The Urban Climate*. New York, NY: Academic Press.

Levinson, H.S. (1982). Parking in a Changing Time. In H.S. Levinson & R.A. Weant (Eds.), *Urban Transportation: Perspectives and Prospects* (214-219). Westport, Connecticut: ENO Foundation for Transportation.

Lilly, S.J. (2001). *Arborists Certification Study Guide*. Champaign, IL: International Society of Arboriculture.

Lindsey, P., & N. Bassuk (1991). Specifying Soil Volumes to Meet the Water Needs of Mature Urban Street Trees and Trees in Containers. *Journal of Arboriculture*, 17, 141-149.

Longstreth, R. (1992). The Perils of a Parkless Town. In M. Wachs & M. Crawford (Eds.), *The Car and the City: the Automobile, the Built Environment, and Daily Urban Life* (141-153). Ann Arbor: Univ. of Michigan Press.

Lynch, K. & G. Hack. (1984). *Site Planning* (3<sup>rd</sup> ed.). Cambridge, Massachusetts: MIT Press.

McPherson, E.G. (2001). Sacramento's Parking Lot Shading Ordinance: Environmental and Economic Costs of Compliance. *Landscape and Urban Planning*, 57, 105-123.

Moffat, A.S., M. Schiler, & Staff of Green Living (1993). *Energy-Efficient and Environmental Landscaping*. South Newfane, VT: Appropriate Solutions.

Neely, D. (1978). Diagnosis and Control of Tree Disease Damage. *Proceedings of the National Urban Forestry Conference*, Washington, DC, 2, 541-545.

Olgay, V. (1963). *Design with Climate*. Princeton, NJ: Princeton University Press.

Owens, J.B. (1978). Urban Streets and Parking Spaces: Blight or Benefit. *Proceedings of the National Urban Forestry Conference*, Washington, DC, 1, 222-233.

Palladio, A. (1977). *The Four Books on Architecture* (R. Tavernor, & R. Schofield Trans.). Cambridge, MA: MIT Press. (Original work published 1570)

Pomerantz, M., H. Akbari, A. Chen, & H. Taha (1997). *Paving Materials for Heat Island Mitigation* (LBL-38074). Berkeley, CA: Lawrence Berkeley National Laboratory.

Pomerantz, M., B. Pon, H. Akbari, & S.C. Chang (2000). *The Effect of Pavements' Temperatures on Air Temperatures in Large Cities* (LBNL-43442). Berkeley, CA: Lawrence Berkeley National Laboratory.

Scott, K.I., J.R. Simpson, & E.G. McPherson (1999). Effects of Tree Cover on Parking Lot Microclimate and Vehicle Emissions. *Journal of Arboriculture*, 25 (3), 129-142.

Smith, T.P. (1988). *The Aesthetics of Parking: An Illustrated Guide* (Planning Advisory Service Report No. 411). Chicago, IL: American Society of Planning Officials.

Spirn, A.W. (1984). *The Granite Garden: Urban Nature and Human Design*. New York: Basic Books.

Taha, H. (1997). Urban Climates and Heat Islands: Albedo, Evapotranspiration, and Anthropogenic Heat. *Energy and Buildings*, 25, 99-103.

Taha, H., S. Douglas, & J. Haney (1997). Mesoscale Meteorological and Air Quality Impacts of Increased Urban Albedo and Vegetation. *Energy and Buildings*, 25, 169-177.

Taha, H., S. Konopacki, & S. Gabersek (1999). Impacts of Large-Scale Surface Modifications on Meteorological Conditions and Energy Use: A 10-Region Modeling Study. *Theoretical and Applied Climatology*, 62, 175-185.

Trowbridge, P.J., N.L. Bassuk (2004). *Trees in the Urban Landscape: Site Assessment, Design, and Installation*. Hoboken, NJ: John Wiley & Sons, Inc.

U.S. Census Bureau, Population Division (2003, April). 100 Fastest Growing US Counties with 10,000 or more Population

- in 2002: July 1, 2001 to July 1, 2002 (Table CO-EST2002-10). Retrieved February 4, 2004, from the US Census Bureau web site: [eire.census.gov/popest/data/counties/tables/CO-EST2002/CO-EST2002-10.php](http://eire.census.gov/popest/data/counties/tables/CO-EST2002/CO-EST2002-10.php)
- U.S. Environmental Protection Agency (1997, October). *Climate Change and Human Health*. Retrieved February 4, 2004, from the Environmental Protection Agency Web site: [http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/SHSU5BNNXJ/\\$File/ccandpublichealth.pdf](http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/SHSU5BNNXJ/$File/ccandpublichealth.pdf)
- U.S. Environmental Protection Agency (1998, September). *Climate Change and North Carolina*. Retrieved February 4, 2004, from the Environmental Protection Agency Web site: <http://www.epa.gov/cgi-bin/claritgw>
- U.S. Environmental Protection Agency (2003, October). *Heat Island Effect*. Retrieved February 4, 2004, from the Environmental Protection Agency Web site: <http://yosemite.epa.gov/oar/globalwarming.nsf/webprintview?ActionsLocalHeatIslandEffect.html>
- U.S. Environmental Protection Agency, Climate Protection Division (2000, July). *The Power to Make a Difference: Energy Star and Other Partnership Programs*. Retrieved February 4, 2004, from the Environmental Protection Agency Web site: <http://epa.gov/cpd/pdf/cpdann99.pdf>
- Vitruvius, P. (1914). *The Ten Books on Architecture* (M.H. Morgan, Trans.). Cambridge, MA: Harvard University Press. (Original work published c.40 B.C.)
- Warner, G.E. (1991). *Predicting Pedestrian Use on Outdoor Urban Plazas Utilizing Climate/Behavior Models*. MLA thesis, Virginia Polytechnic Institute and State University.
- Whitcomb, C.E. (1987). *Establishment and Maintenance of Landscape Plants*. Stillwater, OK: Lacebark Publications.
- Wolf, K.L. (2004, February). *Trees, Parking and Green Law: Strategies for Sustainability*. Stone Mountain, GA: Georgia Forestry Commission, Urban and Community Forestry.
- Additional References
- Alexander, L.A. Ed. (1987). *Better Downtown Parking: Increasing the Supply and Managing it Better*. New York: Downtown Research and Development Center.
- Boldon, C.M. (1971). *Parking Standards Study*. California: Parking Standard Design Associates.
- Bosselmann, P., E. Arens, K. Dunker, & R. Wright (1990). Sun, Wind, and Pedestrian Comfort: A Study of Toronto's Central Area. *Cityplan '91*, 25, City of Toronto, Planning & Development Department.
- City of Toronto, Planning & Development Department (1990). Environmental Backgrounder: Environmental Planning Issues and Concerns in the City of Toronto. *Cityplan '91*, 9 (1).
- Dove, M.R. (1982). *A Method for Including Bioclimatic Analysis in the Development of Landscape Ordinances*. MURP thesis, Virginia Polytechnic Institute and State University.
- Field, R., H. Masters, & M. Singer (1982). Status of Porous Pavement Research. *Water Research*, 16, 849-858.
- Gibbons, J. (1999). Parking Lots. *Nonpoint Education for Municipal Officials* (NEMO technical paper no. 5). Haddam, CT; University of Connecticut.

Hanson, S. (1995). Getting There: Urban Transportation in Context. In Hanson, S. (Ed.), *The Geography of Urban Transportation* (2<sup>nd</sup> ed.) (3-25). New York, NY: Guilford Press.

Heschong, L. (1989). *Thermal Delight in Architecture*. Cambridge, MA: MIT Press.

Kühn, E. (1959, Spring). Planning the City's Climate. *Landscape*, 8 (3), 21-23.

Liao, C.J., & I.I. Cech (1977). Effect of Abrupt Exposure to Outdoor Heat on Humans Accustomed to Air Conditioning. *Urban Ecology*, 2, 355-369.

Maco, S., & E.G. McPherson (2002). Assessing Canopy Cover Over Streets and Sidewalks in Street Tree Populations. *Journal of Arboriculture*, 28 (6), 270-276.

McPherson, E.G., D.J. Nowak, & R.A. Rowntree (1994). Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project (General Technical Report NE-186). USDA Forest Service: Northeast Forest Experiment Station.

Miller, C.G. (1988). *Carscape: A Parking Handbook*. Columbus, IN: Washington Street Press.

Miller, R.W. (1988). *Urban Forestry: Planning and Managing Urban Greenspaces*. Englewood Cliffs: NJ, Prentice Hall.

Robinette, G.O. (1972). *Plants, People, and Environmental Quality*. Washington, DC: National Park Service.

Robinette, G.O. (1976). *Parking Lot Landscape Development*. Reston, VA: Environmental Design Press.

Robinette, G.O. (1977). *Landscape Planning for Energy Conservation*. Reston, VA: Environmental Design Press.

Robinette, G.O. (1983). *Energy Efficient Site Design*. New York: Van Nostrand Reinhold.

Rowntree, R.A., R.A. Sanders, J.C. Stevens, & U.S. Forest Service (1982). Evaluating Urban Forest Structure for Modifying Microclimate: The Dayton Climate Project. *Proceeding of the Second National Urban Forestry Conference*, Cincinnati, OH, 136-142.

Southern California Edison (1991). Trees: Saving Energy Naturally. In Akbari, H., S. Davis, S. Dorsano, J. Huang, & S. Winnett (Eds.), *Cooling our Communities: A Guidebook on Tree Planting and Light-Colored Surfacing* (LBL-31587) (5-26). United States Environmental Protection Agency and Lawrence Berkeley Laboratory.

Thurrow, C. (1983). *Improving Street Climate Through Urban Design* (Planning Advisory Service Report No. 376). Chicago, IL: American Planning Association.

Turner, T. (1998). *Landscape Planning and Environmental Impact Design* (2<sup>nd</sup> ed). London: UCL Press.

Vitum, J.S. (1974). *The Physical Structure of City Space and its Affect on Microclimate and Human Thermal Comfort*. MLA thesis, State University of New York, Syracuse.

Wilson, A. (1965, Spring). Climate and the Sprawl of Cities. *Landscape*, 14, 20-21.

Witford, D.K., & Kanaan, G.E. (1972). *Zoning, Parking, and Traffic*. Saugatuck, CT: ENO Foundation for Transportation.

Wong, T.W. (1996). *Parking Lot Shade Study: A Critical Examination of Davis Parking Lot Tree Shade*. Senior thesis, University of California, Davis.

## **Appendix A: Planting Guidelines and Maintenance Standards**

### Planting Guidelines

Research has been done to illustrate the best way to plant an urban tree in order for it to reach its full potential in size and lifespan. Several factors go into good tree planting including: digging a good planting hole, soil conditions, aeration, drainage, and irrigation.

*Planting Holes-* Compacted soil is probably the biggest problem hindering tree growth in parking lots. Roots need loose soil to provide growing room, aeration, and drainage. Whitcomb (1987) suggests that the key to digging a hole for planting trees

and shrubs is that wider is better than deeper. His reasoning behind this suggestion is that the roots for most plants only grown within the upper ten to twelve inches of soil. Holes only need to be dug to the depth of the root flare and should be dug two to three times the width of the root ball depending on the type of plant (Harris, Clark, & Matheny, 1999). Digging deeper holes will allow the soil to settle, leaving the top of the plant a couple of inches below ground level. This depression will allow water to settle in the planting hole leading to rotting stems and/or roots, disease problems and plant stress (Whitcomb, 1987). Harris et al. (1999) have recommended digging vertical walls for the planting pit instead of sloping walls. This would prevent excessive water from washing into the pit and drowning the lower portion of the root ball.

*Soils-* Providing enough soil volume for roots to grow is essential for the health of the tree considering that is where the tree finds water, nutrients, and oxygen for acquisition (Grabosky, Bassuk, & Trowbridge, 2002). Proper soils are a major key to the health of a plant. The soils need to be rich in water, minerals, and nutrients and the plant needs to be able to use those soil characteristics to grow. Many times the problems with soils are that the tree or shrub is unable to acquire the nutrients from the soil because they are “locked in.” Iron and manganese are chemically bound in alkaline soils, for example, and the roots cannot separate the minerals from the soil in order to use them

(Neely, 1978).

Soils in planting pits should be tested to ensure that they are well balanced; poor soils should be removed and replaced with better soils. Good soils are those that are well aerated, have the capacity to hold plenty of nutrients, have the ability to hold water but also be able to drain well. Amending compacted soils with organic materials is not recommended because this procedure has not been shown to have any beneficial effect on the growth of the tree (Harris et al., 1999; Whitcomb, 1987). A better solution is simply to till up the compacted soil, allow it to settle back into the pit, and then planting in the loosened soil.

The amount of soil that a typical tree needs to grow in the urban environment is an issue of high debate. Much is written about the size of the hole in which a tree is to be planted, but perhaps a better way to determine the size of the hole to dig is to decide how much soil the plant needs. Horticulturists at Cornell’s Urban Horticulture Institute have indicated a general rule of thumb for the amount of soil a tree needs for optimal growth. This rule of thumb is two cubic feet of soil for every one square foot of crown projection to a depth of about three feet (Grabosky et al., 2002). Supplying this much soil underneath the canopy of a newly planted tree will ensure the tree will receive proper room to grow and anchor itself into the ground. Providing this much soil for one tree in the urban landscape may seem like an impossible task because of the small amount of room allotted for trees in the landscape, but

planting trees in groups can help solve this dilemma.

Planting grouped trees in the urban landscape is a great way to provide plenty of soil for trees to grow. Grabosky et al. (2002) suggest taking a look at rural trees in order to assess the needs of urban trees. Trees in the forest, for example, do not need to be spaced out far from each other in order to survive. They can grow in fairly close proximity to one another as long as their roots can intertwine in the quest to find enough soil volume to sustain growth. The same should be true in the urban environment. Grouped trees can be planted in clusters within larger planting islands in order to provide more soil for the tree's roots. Clustering, however, is not the only way to provide more soil area for roots. New soils are being developed for use under roads, sidewalks, and parking lots that will allow for roots to easily penetrate through them, facilitating water and nutrient uptake.

Recently, a new soil has been created and tested at Cornell University that has the capability of being compacted to standards suitable for parking lots and roads, while still allowing roots to easily penetrate. This type of soil is called CU structural soil. CU structural soils are "a designed medium which can meet or exceed pavement design and installation requirements while remaining root penetrable and supportive of tree growth" (Bassuk, Grabosky, Trowbridge, & Urban, 1998). The supportive structure of these soils are large aggregates that can be compacted to the strength necessary to support roads, sidewalks, and parking lots. Yet there

is plenty of space between these aggregate layers where soil can fill the gaps bringing nutrients and holding water for the vegetation to use.

Structural soils can be used under any rigid paving surface and can be compacted to whatever strength is required by local codes. Because of the large porous nature of the soil, roots can easily find room to grow through the compacted soil, unlike the typical compacted soils found under roads, sidewalks, and parking lots. Giving roots room to grow underneath the surface of the pavement will allow for a better root system for the growing tree as well as decrease the amount of damage roots cause to sidewalks and roadways.

*Aeration-* The compacted soil under parking lots prevents oxygen from reaching plants roots leading to suffocation. Porous pavements as well as structural soils that allow for compaction but still contain air holes are great for providing the vertical movement of air down to the roots of trees and shrubs. As long as the soil is well-drained, oxygen will be able to penetrate through the pavement and soil to the roots. Drainage is a large part of ensuring that roots are provided with an adequate amount of oxygen.

*Drainage-* To determine whether the planting bed needs to be equipped with extra drainage, a percolation test should be

administered. If the soil does not drain well, then an internal drainage system must be provided to carry water away from roots.

Many times planting beds are used as a water retention area in the urban landscape. These retention areas can be very beneficial to stormwater treatment systems and downstream ecosystems because the planters help to filter pollutants out of the water before it is either sent to the city's stormwater treatment plant or returned to the groundwater. If the soils in the planter are not able to drain this stormwater properly, then other options should be made for the excess water removal. Any time soils do not drain well, or are being used for water retention areas, specific plants that can tolerate high levels of soil moisture should be used. These types of plants should be listed in a master tree list to help the developer choose the proper types of vegetation.

*Irrigation*- The oppressive heat caused by parking lots during the summer months can take a toll on parking lot landscaping. Plants need to have plenty of water during this time to ensure their survival. Irrigation may be required in areas with hot, dry summers but needs to be controlled so as not to drown the plants.

Factors determining the amount of water needed for vegetation in the urban landscape include: weather patterns, length of day, amount of previous irrigation or rainfall, depth and spread of roots, and size of canopy (Harris et al., 1999). There are various

types of sprinkler systems that can be installed in order to keep vegetative beds thoroughly watered throughout the growing season. Plants with similar watering needs should be planted together to ensure the most effective watering practices.

Many municipalities are concerned with water conservation efforts, especially during summer months when rainfall is slight. In these cases, it is important to know how much water is needed for the plants to sustain themselves. During critical growing seasons, more water can be provided to ensure health and vigor, but other times may receive less water. It is also important when choosing which plants to include in urban areas, such as hot, dry parking lots, to choose plants that can handle hot, dry situations. Many plants can thrive with little irrigation and should be considered for planting in such land uses.

Another option to reduce the amount of water needed in the urban landscape is by mulching. Mulching is beneficial to keeping planting beds moist in several ways. First, mulching helps to insulate the planting bed so that moisture cannot escape into the air by means of evaporation. Secondly, using mulch instead of grass around the base of trees will eliminate the competition between the two species for water and nutrients.

Other benefits of mulching include: reduced soil compaction, reduced erosion, and improving soil tilth by supplying plant nutrients as they decompose (Trowbridge & Bassuk, 2004). The use of organic mulches like bark, pine needles, and compost will

benefit planting beds the most and should be encouraged over the use of gravel or brick chips. Mulching depth should be anywhere from three to four inches (Lilly, 2001; Trowbridge & Bassuk, 2004).

Another important factor that should be taken into consideration when planting urban vegetation is the time of year that trees and shrubs are planted. Many times trees and shrubs are simply planted when the construction allows them to be planted. This is often during summer or winter months when conditions are not suitable for planting. Trees should mainly be planted during spring or fall months when soil and air temperatures are moderate and rainfall is frequent. Studies have shown that planting in the spring will give a ten percent higher survival rate than planting in the fall for bare-root and ball and burlap trees and shrubs (Cool, 1978). Whitcomb (1987), however, states that plants that are container grown in the nursery have a better chance of survival if planted in the fall. The choice between these two seasons is one that will highly depend upon the climatic zone in which the planting is being done.

#### Plant Maintenance

Properly planting vegetation in the urban landscape is only half of the battle when striving to provide the proper growing atmosphere for urban vegetation. Trees need to be maintained and cared for in the urban environment in order to remain strong

and healthy. Healthy trees will have a better chance of resisting disease and pest infestation and will provide more environmental benefits to the landscape. Keeping trees healthy will also reduce costs in the long run as tree removal and replacement practices are not cheap. Also, maintenance of young trees is much less expensive and easier than maintenance of mature trees. The small initial investment in plant maintenance early on will benefit the property owner later by reducing maintenance problems and increasing plant benefits.

The most important decision in planting successful vegetation is choosing the proper plant or tree for the location (Lilly, 2001). Planting an appropriate species in the urban landscape will minimize the amount of maintenance one has to administer. Maintenance of the urban vegetation includes everything that must happen in between planting the tree and when the tree will need to be removed. Plant maintenance can be divided into three categories: growth management, damage management, and insect and disease management (Grey & Deneke, 1986).

*Growth Management*- There are two types of growth control that can be used to manage the urban landscape if needed: the first type is that which controls, or redirects, the growth of the urban vegetation, and the second is the type of control which stimulates the growth of trees (Grey & Deneke, 1986). The first type of growth control involves pruning trees and shrubs to either

contain their growth or keep it from growing in the way of pedestrians or traffic. Keeping trees and shrubs properly pruned will not only protect people and automobiles from being injured by overextending branches, but will also protect the tree or shrub from being injured. Pruning is not a task that should be done without proper training because it can have devastating effects on the tree or shrub.

Topping, for example, is an act of severe pruning that can have devastating effects on the tree itself and is not an acceptable pruning practice (American National Standards Institute, 2001). Topping is a term used for completely pruning the entire canopy from the tree resulting in stubs instead of limbs. This has been a practice performed by many municipalities in order to reduce the amount of limbs that fall into roads or onto houses during winter storms. This practice is hazardous to the tree's health because it leaves open wounds in the tree for disease and pests to enter.

Pruning is not necessarily a process that needs to be administered every year. Pruning trees is a practice that is vital to the welfare of a tree when the tree is young. Making sure that a tree develops a good structure when young will almost ensure that that tree will grow into a nicely shaped, problem-free tree.

Pruning can be done on mature trees to thin out thick canopies. Thinning canopies can improve the life of the tree in several ways. First, thinner canopies allow sunlight to penetrate deep into the canopy of the tree making sure that the center

receives sufficient sunlight. Allowing more light to penetrate through the tree will also allow plants beneath the canopy of the tree to receive adequate sunlight for growth. The second benefit to pruning a tree's canopy is that it will allow some wind to pass through the canopy instead of being trapped. This will reduce the risk of trees being blown over by strong winds (Harris et al., 1999).

The second type of management is growth enhancement. Growth enhancement includes anything that will support and facilitate the tree or shrub in surviving in the urban environment. This includes irrigation, fertilization, and the removal of other weeds and vegetation that may compete for nutrients and water (Grey & Deneke, 1986).

Fertilizer should be applied on an as needed basis in order to amend soils that may have been stripped of nutrients as the plant uses them. Fertilizer should be applied so that they are available for roots when they are in a growing stage. The fertilizer should be of a slow-release type and should be placed near the trunk to the dripline or just beyond (American National Standards Institute, 1998).

*Damage Management*- Damage control includes anything that needs to be done in order to correct a problem that has occurred, like removing broken branches after an ice storm. Many times damage control can be prevented if the proper steps in

growth control have been taken. Pruning trees is a great way to prevent damage to trees and shrubs by keeping them out of harm's way. Along with pruning, damage control includes: "construction and grade change precautions, cabling and bracing, wrapping, mulching to discourage damage by lawnmowers, construction of physical barriers, posting of signs, and policing," as well as education (Grey & Deneke, 1986, p. 166).

Damage control begins with the proper planting of a tree, shrub, or other vegetation in the landscape. Properly planting a tree or shrub in the landscape can dramatically reduce the need for maintenance later on by ensuring that a tree or shrub recovers from transplant shock. Any time a plant is damaged in some way, damage control is required to make sure that the plant is tended to in order to prevent further damage.

Another damage control device, especially for trees and shrubs within parking lots, is wheel stops and/or curbing. Providing these devices around vegetated islands in parking lots will keep the plants protected from automobile overhangs, opening doors, and wheels. If necessary, curbing can also prevent polluted stormwater from entering certain planting islands that may be sensitive to pollutants or excessive amounts of water.

*Insect and Disease Management-* Insect and disease management includes the following elements: "knowledge of insect and disease life cycles, monitoring, decision making, physical

capability for control application, and legal authority for action" (Grey& Deneke, 1986, p. 166). Knowledge of insect and disease life cycles will help to determine the appropriate action to take. It is also important for the person checking the vegetation to know the difference between pests and diseases that are harmful to the plant and those that are beneficial (Harris et al., 1999). Many insects and diseases have little adverse effect on the tree or shrub they are infecting. In these cases, treatment may not be necessary as many diseases do not cause permanent injury to the plant. It may be sufficient to simply allow the life cycle of the insect or disease to run its course and not worry about treating the vegetation. After the life cycle is complete the plant may be able to correct itself, especially if the tree was healthy to begin with.

Monitoring is a great way to catch a pest or disease problem before it gets out of control. Monitoring will allow the city to detect problems early and treat them before that problem becomes an issue city-wide. It will be much easier to treat a single tree or clustered group of trees than to treat every tree within the city.

Treating insect pests and diseases with chemicals is not always the best method to manage them. Not only can this be hazardous to the health of humans, but chemicals can also kill predators that feed on the pests. Other options are available for the elimination of noxious pests. William and Helga Olkowski of the Department of Biological Control, University of California,

Berkeley, have studied and suggested ways to combat insect and disease problems in Berkeley through the understanding and management of ecosystems (Grey & Deneke, 1986). What they have found is that many insects can be eliminated by knowing what those insect's natural enemies are and introducing those enemies into the city. This avoids the use of chemicals and sprays to eliminate pests and rids the city of the problem safely. Other options that can be administered that do not require the use of chemicals and sprays are the use of pruning to remove and rid the city of those parts of the tree that are heavily infested. Using high-powered water sprays and insect tapes are also safe management practices to remove pest from the city.

The city can take a pro-active stand in fighting problems with pests and disease by providing a master tree list for use throughout the city. The tree list should include trees that are resistant to pest and diseases but still provide the necessities needed in the urban environment (shade, screening, etc.) By requiring landscapes to include only, or primarily, trees from the provided lists, cities and property owners could save money that would otherwise have been used on treating pests.

**Appendix B: Sacramento,  
California's Supplemental Manual**

**CITY OF SACRAMENTO**

**PARKING LOT TREE SHADING DESIGN  
AND MAINTENANCE GUIDELINES**



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**I. INTRODUCTION / PURPOSE:**

This document provides standards and guidance for the planting, maintenance, protection, removal and replacement of trees planted pursuant to the parking lot tree shading regulations as defined in the City Code. The purpose of the Parking Lot Tree Shading Design and Maintenance Guidelines is to improve the effectiveness of the City's parking lot shading ordinance. The standards and recommendations in this documents will help to encourage achievement of the City's 50 percent shading requirement for a greater number of parking facilities.

**II. SHADING REQUIREMENTS AND CALCULATIONS:**

The parking lot tree shading ordinance requires that all new parking lots include tree plantings designed to result in 50 percent shading of parking lot surface areas within 15 years.

The shading requirements calculations apply to all new impervious surfacing on which a vehicle can drive including:

- Parking stalls
- All drives within the property line (regardless of length)
- All maneuvering areas (regardless of depth)

Exceptions to the shading calculation include:

- Single family and two family residential parking areas
- Parking structures
- Truck loading areas in front of overhead doors
- Truck maneuvering and parking areas unconnected to and exclusive of any vehicle parking
- Surfaced areas not to be used for vehicle parking, driving or maneuvering, provided they are made inaccessible to vehicles by a barrier such as bollards, curb, or fencing
- Vehicle display, sales, service, and storage areas (parking facilities for these uses are subject to shading requirements)

**Shading Calculations:**

1. If a site has two or more unconnected parking areas, shade is calculated separately for each area. If they are connected by a joining drive, they are calculated as one lot.
2. The amount of shade provided by a given tree is determined by using the appropriate percentage and square footage of the tree crown as indicated on the approved shade tree list (see Appendix A). Shading credit is given in 25 percent increments based on the amount of the tree crown that shades the parking area (see Exhibit A).
3. Overlapping shade does not count twice.

4. Street trees and existing on-site trees that shade parking lots will be given credit.
5. Parking areas under covered stalls (carports) and in garages may be counted toward the amount of required shading provided if these areas are included as part of the total square footage of the surfaced area to be used in the shading calculations. Calculations of how these areas meet shade requirements must be shown and all areas and their dimensions used in shading calculations must be shown on the shading and/or landscaping plan.
6. Provide shade calculations and shade legend. The planting plan may be used as the shade plan provided all required information is listed and the trees are drawn to scale at the size indicated on the approved shade list (see Appendix A).

Shade calculations should indicate:

1. Tree Symbols
2. Tree Type
3. Tree Quantity
4. Surfaced Area (including carports, garages, etc.)
5. Shade Area Required
6. Shade Area Proposed
7. Shading Credit Accorded to Each Tree (F or 100%, TQ or 75%, H or 50%, Q or 25%)

**Sample Parking Lot Shade Calculation Table:**

Symbol	Botanical Name/ Common Name	Quantity @ Full Shade / Sq. Ft.	Quantity @ ¾ Shade / Sq. Ft.	Quantity @ ½ Shade / Sq. Ft.	Quantity @ ¼ Shade / Sq. Ft.	Total (sq. ft.)
T1	<i>Laurus nobilis</i> Sweet Bay	1 @ 491	2 @ 368	5 @ 246		2457
T2	<i>Quercus agrifolia</i> Coast Live Oak		2 @ 722	2 @ 481	2 @ 240	2886
T3	<i>Pinus Patula</i> Jellocote Pine		1 @ 530	7 @ 354		3008
TOTAL TREE SHADE						8351
Surfaced Area:		Parking Lot		16240	TOTAL SURFACED AREA =	17740
		Covered Stalls (garages, carports, etc.)		1500		
SHADE AREA REQUIRED =						8870
If applicable, TOTAL AUXILIARY SHADE* =						1450
TOTAL SHADE PROVIDED =						9801
PERCENT SHADE =						55.2%

\*NOTE: Auxiliary shade is the total parking area under covered stalls (carports, garages, etc.), not the total covered area.

This method allows easy follow-up and coordination when a discrepancy is found in the plan check process.

**III. TREE PLANTING PRACTICES:**

Proper planting practices are essential in achieving the best growth of a tree and shall be utilized in the development of each new parking lot. These practices include, but are not limited to, the following measures:

1. Inside dimensions of tree wells should be a minimum of 6 feet by 6 feet (see Exhibit B). Smaller dimensions may be considered for end island planters that have a minimum surface area of 36 square feet subject to the approval of the City Landscape Architect.
2. Trees should be planted at a distance of one half the required planter size behind a curb. Where a walk falls adjacent to a curb, any 35' crown diameter tree within 10' of the curb face receives 50 percent shade credit. The tree should be planted at a distance of one half the required planter size behind a walk for this credit to apply.
3. Two feet of vehicle overhang into a planter area is allowed, provided the planter is the correct minimum width of six feet (see Exhibit B). Vehicle overhang is not allowed into required setback areas.
4. Provide a mix of tree types (species or cultivars) if more than ten trees are required.
  - If 20 to 40 trees are required, no more than 50 percent of the trees may be of the same type.
  - If more than 40 trees are required, then no more than 25 percent of the trees may be of the same type.
5. The City encourages 20 percent of the tree selection for a site to be oak or other native tree species.
6. Parking lot lighting should not conflict with required shade tree locations or growth. Light standards no greater than 16 feet in height are strongly encouraged. Buildings located close to streets will reduce potential conflicts between trees and free-standing signs.
7. Trees should be planted and soil volume should be amended as described below and shown in Exhibit C.
  - Tree wells should be excavated to a depth of 3 feet or greater before being backfilled.
  - Root barriers should be of a material specifically designed for containing tree roots.
  - Irrigation in tree wells shall be adapted for deep watering.
  - Backfill in planting pit shall be 75 percent native soil and 25 percent soil amendment.
  - Fertilizer tabs should be of slow-release design lasting for a minimum of 10

- months.
  - Entire planters, including backfill, shall be free of aggregate base (or other materials or construction debris detrimental to optimal plant growth).
  - Tree stakes shall be two inches below the lowest scaffold branch and be made of rot resistant material.
  - Trees should be tied loosely in a figure-8 pattern at the lowest point required to keep the tree in an upright position. Trees with trunks too weak to stand alone may be tied at two positions. If a single stake is used, it should be on the side of prevailing wind. If two stakes are used, they should be parallel to prevailing winds.
  - Tree wells and continuous planting islands should include root barriers (24 inches deep) to prevent potential root damage to parking lot surfaces.
8. Continuous planting islands are encouraged to allow for multiple tree plantings and increased rootable soil volume. These islands might also be designed to incorporate surface water runoff treatment measures such as bio-swales (see Exhibits D and E).
  9. Irregular tree well design may be allowed if a minimum of 36 square feet of surface area is provided and adequate rootable soil volume (minimum 85 cubic feet) is incorporated into the tree well planting.
  10. The use of structural soil mixes is encouraged to promote root growth, especially where irregular tree wells are proposed, or extra shading credit is desired.

**Note:** *The use of structural soil mixes is encouraged as they will increase the rootable soil volume as well as reduce the potential for root invasion into parking lot paving.*

EXHIBIT A

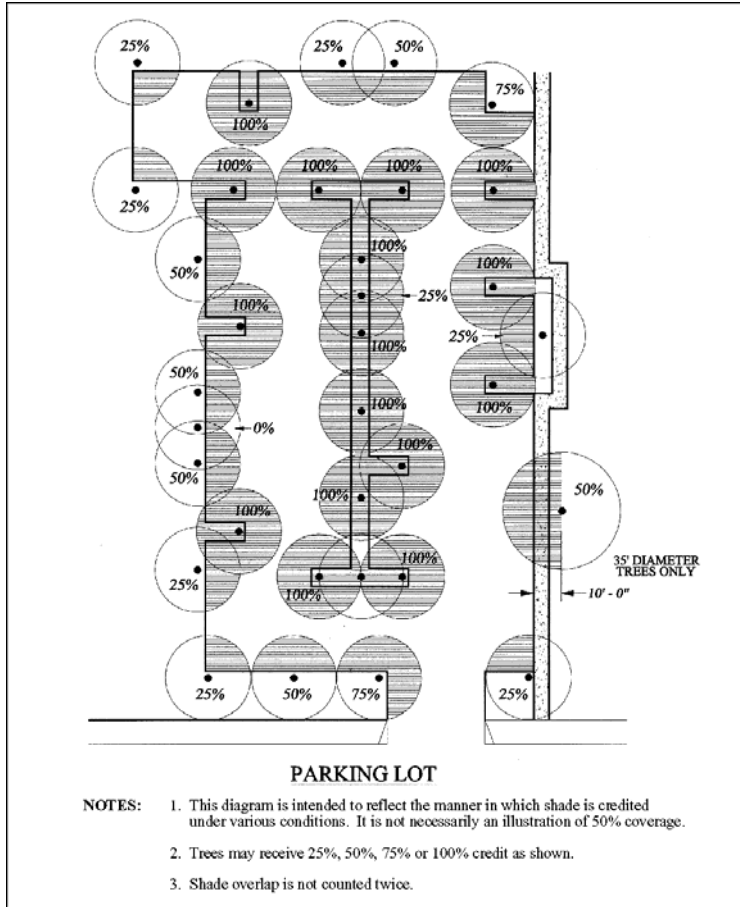
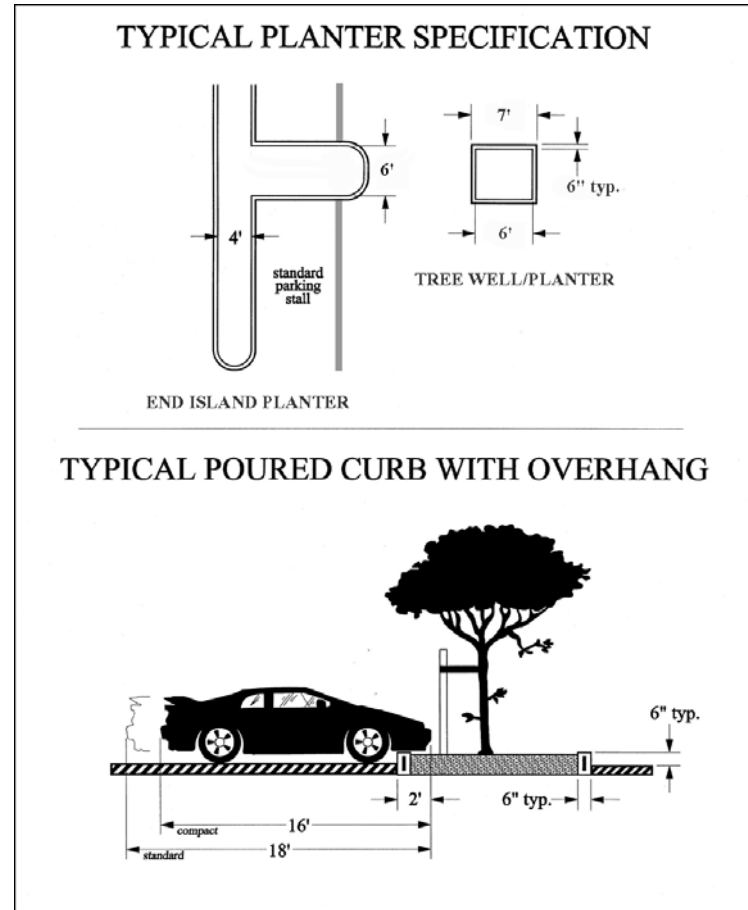
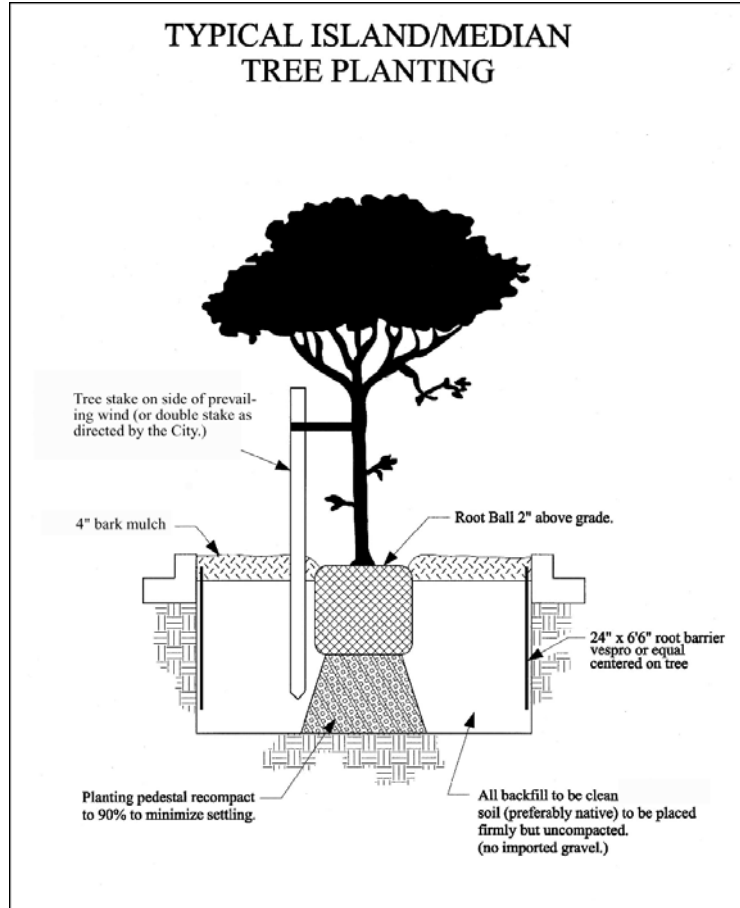


EXHIBIT B



**EXHIBIT C**



**IV. DRAINAGE / WATER QUALITY OPTIONS:**

With early planning and design it is possible for areas required for tree planting to also be used to satisfy the City's requirement to provide on-site treatment of stormwater. In accordance with the Federal Water Pollution Control Act, the City is required to implement a Comprehensive Stormwater Management Program in order to reduce pollutants in urban runoff to the maximum extent practicable.

Parking lots which are part of new developments with one (1) acre or more of impervious area are generally required to provide treatment control measures that capture and treat stormwater runoff through settling, filtration, and/or biodegradation. The treated runoff is then released to the storm drain system or percolated into the ground.

Integrating treatment control measures within areas used for tree shading may significantly reduce land requirements and costs. The following figures (Exhibit D and Exhibit E) describe criteria for vegetated swales and filter strips which can be integrated effectively with tree shading. The Department of Utilities' Stormwater Management Program should be referred to for specific design criteria. Contact the Department of Utilities for plan approval requirements related to stormwater treatment control measures.

Trees planted within stormwater runoff areas should only be species adapted to heavy to moderate irrigation, such as riparian species.

EXHIBIT D

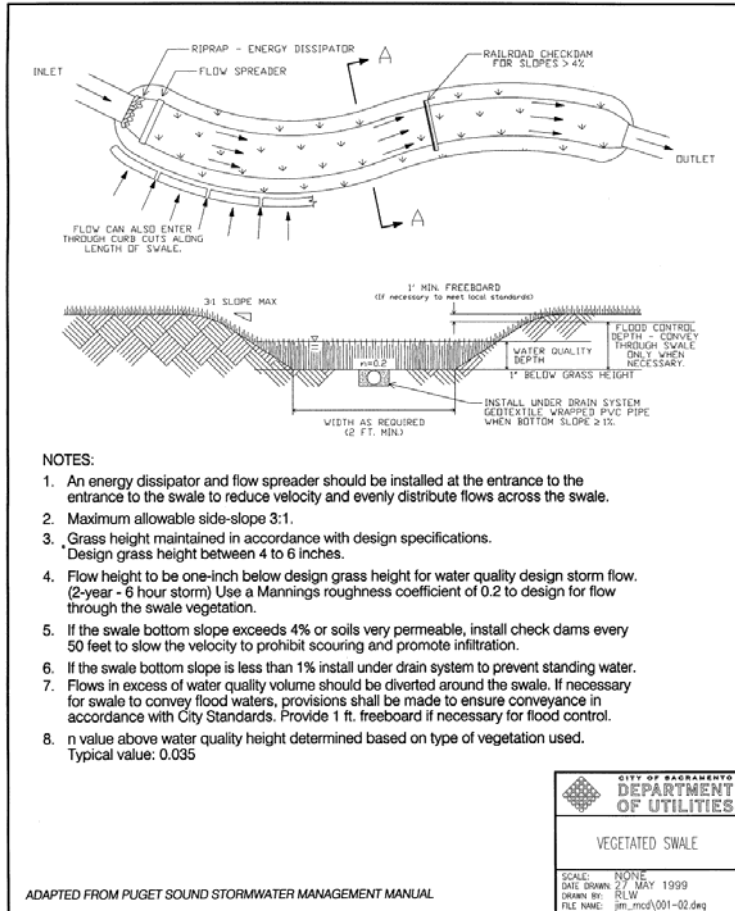
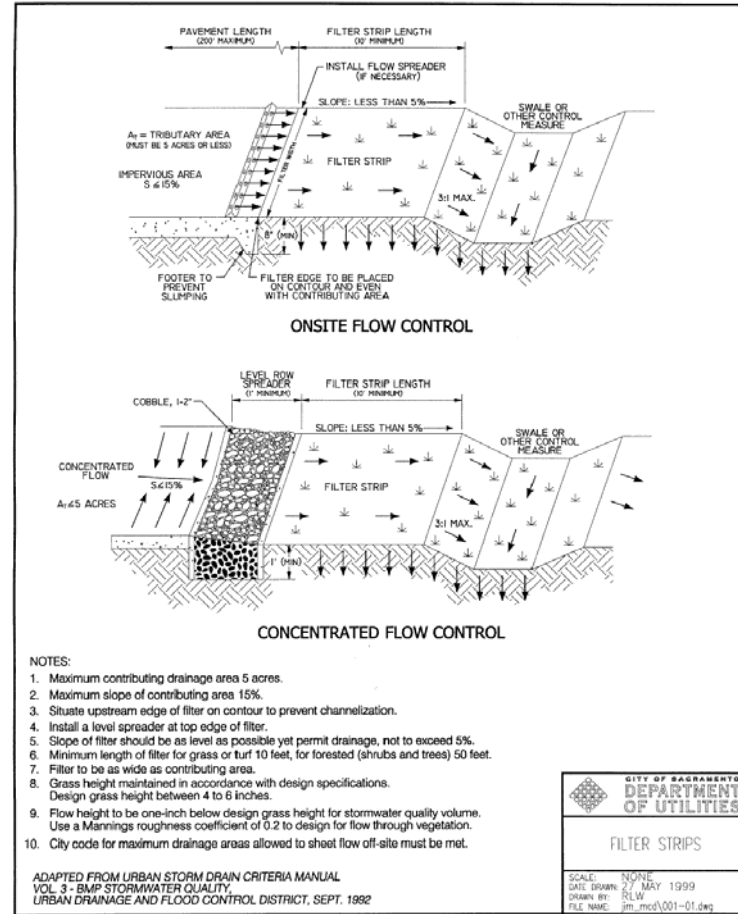


EXHIBIT E



**V. GENERAL SHADING PLAN REQUIREMENTS:**

All projects submitted for building permits must include site grading plans, landscape planting plans and irrigation plans with irrigation calculations. All plans that include parking must also include a shade plan. The planting plan may be used as the shade plan provided the trees are drawn to scale at the size indicated on the approved shade list, and shade calculations are included. Plans will not be accepted into the building permit plan check process unless these items are included. If the parking area under covered stalls (carports, garages, etc.) is to be counted toward the amount of required shading provided, these areas should be included in the calculations as part of the total square footage of the surfaced area, and calculations of how these areas meet shade requirements must be shown.

All landscape, irrigation and shade plans shall be approved by the City of Sacramento (Landscape Architect) or authorized representative. This approval occurs as part of the building permit plan check process.

**All plan submittals must include the following information:**

1. Name and address of project, assessor's parcel number(s) and locator/vicinity map
2. Property lines and easements (Project limits if other than property lines)
3. All site dimensions (This includes planters, parking layout, walks, building distances, covered parking areas, etc. Planter dimensions must be indicated on the inside of the face of curb).
4. Adjoining property use(s) and existing building setbacks
5. Structures (existing and proposed)
6. Walls and fences
7. Roads, walks, curbs and wheelstops
8. Mowing strips and header boards
9. Drop inlets, catch basins, maintenance holes, power poles, etc.
10. Mounds, banks and swales
11. Location of lighting fixtures

**Each sheet must include the following information:**

1. Sheet number and title
2. Scale of drawing
3. North arrow
4. Date drawn
5. Date of revision (Each revision must be submitted with clouds, deltas and dates).
6. Tree legends, plant legends, and/or shade calculations where appropriate
7. Appropriate stamp and signature

**A. Irrigation Plans:**

1. Sprinkler spacing shall not exceed the manufacturer's recommendation.
2. Include irrigation legend defining all symbols used. For each sprinkler head, provide diameter of throw, GPM, precipitation rate and type of head. Denote any other pertinent information such as low angle spray, adjustable spray, diameter, etc.
3. Irrigation system should be designed to meet the City standard pressure flow of 40 psi.
4. Provide backflow prevention device in accordance with the list of approved devices published by the University of California Foundation of Hydraulic Research and Cross-Connection Control. This list is on file in the Building Inspections Division, Commercial Permits counter.
5. Install all valves with threaded unions for easy replacement.
6. Provide controller with at least two (2) programs and at least three (3) start times per station.
7. Provide an irrigation schedule.
8. Provide shut-off valve at point-of-connection.
9. Show locations of all irrigation components and points of connection. Include symbols for each component in a legend (i.e., quick couplers, hose bib and

washer boxes).

- 10. Indicate all main and lateral line sizes. Include class or schedule.
- 11. Provide Maximum Applied Water Allowance (MAWA) calculations.
- 12. No sprinklers on risers shall be installed next to walks, streets and/or pavement. Sprinklers in hazardous locations shall be flush mounted or only high-pop models mounted on single or double swing joints are to be used.
- 13. Irrigation systems shall comply with the City Water Conservation Ordinance.

**B. Landscape Plans:**

- 1. Identify any existing tree species, street trees, or covered parking on site for consideration in shade credit calculations.
- 2. Show location and size of all existing trees and identify those that are to be removed. Existing trees shall be preserved whenever possible and shall be given shading credit, if applicable. No tree over two (2) feet in diameter at breast height shall be removed without specific approval of the City Arborist. A tree removal permit is required for City street trees and heritage trees.
- 3. Planters in parking lots shall be protected with minimum six (6) inch high/wide concrete curbs. Identify type of curb (extruded or poured). If extruded curbing is used, a detail must be provided to clarify planter width available. All reference to planter size is to clear inside soil width, excluding surrounding curbing and asphalt or foundation intrusions (see Exhibit B).
- 4. Show location of all proposed trees and shrubs. All shrubs shall be drawn to reflect the average specimen size at maturity. All shade trees shall be drawn to the size indicated on the Shade Tree List (Appendix A) which shows the specimen size at 15 years of age.
- 5. The soil surface of all planters shall be covered with living groundcover and/or mulch within two (2) years. Exceptions include areas covered with pedestrian pathways and decorative hardscape (i.e. art, archways, arbors, etc.). If mulch is used, spread two (2) inches to six (6) inches of shredded mulch (no wood chips), not to exceed curb or retaining device. Bark mulch is not allowed in a planter area adjacent to a public right-of-way unless six (6) inch curbing is provided.
- 6. Show the types, quantities and sizes of all trees, shrubs and groundcover. Parking lot shade trees shall be a minimum 15 gallon size.

- 7. All plants and trees shall be listed by correct botanical name and common name.
- 8. Lawn shall be indicated by common name of species and method of installation (seed, sod or hydromulch). Sloped areas specifically designed for grass shall be sodded or hydromulched.
- 9. All parking lots must be screened from view of City streets by either a three (3) foot high earth berm or shrubbery that can be easily maintained at thirty (30) inch height. Minimum inside planter width is four (4) feet.
- 10. No tree shall be planted within the sight clearance area of driveways or street/alley intersections. Coniferous trees shall not be planted within five (5) feet of the sight clearance areas.
- 11. Shrubs must be maintained at a 30" maximum height in site clearance areas.
- 12. Provide landscape details (i.e., soil preparation, tree staking, etc.) where appropriate.

**Note:** *When planting under power lines, consider tree height. Use species with a maximum height of 25 feet.*

**C. Grading Plans:**

- 1. Grading plans showing drainage of all planting areas and heights of mounds shall be provided. Include contour intervals.
- 2. Mounds shall not exceed a three-to-one (3:1) slope.
- 3. Mounds over 30 inches high shall not be placed in sight clearance areas.

**D. Maintenance:**

- 1. Tree trimming and removal permits are required from City of Sacramento Tree Services to prune or remove parking lot shade trees. There is no cost associated with these permits.
- 2. All pruning work shall be completed pursuant to International Society of Arboriculture (ISA) and American National Standards Institute (ANSI) standards.

- Removed trees must be replaced. The formula for replacement shall be as follows:

Any required trees or other plantings that die or are improperly maintained shall be replaced with healthy specimens of similar species and size. However, replacement trees shall not be required to exceed 48" box size. Removal and replacement of trees that have caused damage to city sidewalks or other city infrastructure shall be reviewed and approved by the City Arborist prior to tree removal. If the removed tree is greater than 48" boxed tree size, then a 48" box tree shall be planted.

**VI. TREES FOR PARKING LOT SHADING:**

The list of trees for parking lot shading, identified in Appendix A, was compiled to aid in species selection. Any trees proposed to be planted that are not on the list must receive approval from the City Landscape Architect or the City Arborist. Such requests must be submitted through the City Building Division of the Planning and Building Department.

Selection of the trees listed is based on adaptability to parking lot conditions. The characteristics identified in the tree list are provided to help select a good shade tree. The species listed are not suitable for all situations. Consultation with a nursery representative or landscape architect is desirable before any selections are made. Professional guidance is recommended to assure that optimal design is achieved to meet the needs of each development. Proper planting procedures, optimal spacing distance, soil, water requirements and maintenance programs should be ascertained at the start of the landscape project. It is important to note that proper planting procedures may include digging past the hardpan layer to assure deeper and proper growth.

All other energy conservation ordinances, resolutions and measures are available from the Planning and Building Department. Building permit plan approval will be based on these guidelines.

**Note:** *The use of structural soil mix within the planters is encouraged in planting locations requiring supplemental root growth area. Structural soil mixes should be considered in proposals for irregular shaped tree wells.*

**APPENDIX A**

**Tree List**

**35' DIAMETER TREES**

Shading Calculations: 100% = 962 SQ. FT. 75% = 722 SQ. FT. 50% = 481 SQ. FT. 25% = 240 SQ. FT.

<u>Botanical Name</u> <u>COMMON NAME</u>	<u>Minimum Planter Width</u>	<u>Height To:</u>	<u>Growth</u>	<u>Roots</u>	<u>Remarks</u>
Celtis australis EUROPEAN HACKBERRY	6'	50'	Moderate	Deep	Deciduous, mod. irrigation, fruit
Celtis sinensis CHINESE HACKBERRY	6'	40'	Moderate	Deep	Deciduous, avoid clay soils
Celtis occidentalis COMMON HACKBERRY	6'	60'	Moderate	Deep	Deciduous
Fraxinus americana 'Autumn Purple', 'Chicago Regal' WHITE ASH	6'	40'	Fast	Shallow	Deciduous, fall color, Mod. irrigation
Fraxinus pennsylvanica 'Patmore', 'Leprechaun', 'Centerpoint' GREEN ASH	6'	40'	Fast	Shallow	Deciduous, some insect and disease damage
Fraxinus uhdei EVERGREEN ASH	6'	40'	Fast	Medium	Evergreen, prone to insect and disease damage
Platanus acerifolia 'Yanwood', 'Bloodgood', x hispanica 'Columbia' LONDON PLANE TREE	6'	70'	Fast	Shallow	Deciduous, red spider, powdery mildew, anthracnose, smog tolerant
*Platanus racemosa CALIFORNIA SYCAMORE	6'	60'	Moderate	Medium	Deciduous, red spider, powdery mildew, anthracnose
*Quercus agrifolia COAST LIVE OAK	6'	40'	Moderate	Deep & greedy	Evergreen, drought tolerant
Quercus coccinea SCARLET OAK	6'	60'	Fast	Deep	Deciduous
Quercus ilex HOLLY OAK	6'	50'	Moderate	Deep	Evergreen, has caterpillars, drought tolerant

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*Quercus lobata VALLEY OAK	6'	60'	Moderate	Deep	Deciduous, litters
Quercus macrocarpa BUR OAK	6'	50'	Moderate	Deep	Deciduous, litters
Quercus robur ENGLISH OAK	6'	50'	Moderate	Deep	Deciduous, litters
Quercus rubra RED OAK	6'	60'	Moderate	Deep	Deciduous, avoid clay soils
Quercus suber CORK OAK	6'	70'	Moderate	Deep	Evergreen, drought tolerant
Quercus virginiana SOUTHERN LIVE OAK	6'	60'	Moderate to Fast	Deep	Evergreen, tolerates moisture

**30' DIAMETER TREES**

Shading Calculations: 100% = 706 SQ. FT. 75% = 530 SQ. FT. 50% = 354 SQ. FT. 25% = 177 SQ. FT.

<u>Botanical Name</u> <u>COMMON NAME</u>	<u>Minimum Planter Width</u>	<u>Height To:</u>	<u>Growth</u>	<u>Roots</u>	<u>Remarks</u>
Acer fremanii 'Autumn Blaze' AUTUMN BLAZE MAPLE	6'	50'	Moderate	Deep	Deciduous, fall color, mod. irrigation
Acer platanoides 'Crimson Sentry' CRIMSON SENTRY MAPLE	6'	40'	Moderate	Shallow	Deciduous, fall color
Acer rubrum 'October Glory' OCTOBER GLORY RED MAPLE	6'	50'	Moderate	Medium	Deciduous, deep watering to keep roots down
Eucalyptus microtheca Coolibah	6'	40'	Fast	Medium	Drought and soil tolerant
Ginkgo biloba MAIDENHAIR TREE	6'	40'	Slow	Deep	Deciduous, gawky when young, use male tree only
Koelreuteria paniculata, bipinnata, elegans GOLDENRAIN, CHINESE FLAME, FORMOSAN FLAME	6'	35'	Slow Moderate	Deep	Deciduous, mod. irrigation, flowers, litters
Magnolia grandiflora SOUTHERN MAGNOLIA	6'	50'	Slow	Deep	Evergreen, litters, Moist, well drained, slightly acid soil
Pinus patula JELECOTE PINE	6'	30'	Fast	Medium	Evergreen, drought tolerant

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Pistacia chinensis CHINESE PISTACHE	6'	50'	Moderate	Deep	Deciduous, drought tolerant, fall color, young tree lopsided and gawky
Quercus frainetto 'Forest Green' FOREST GREEN OAK	6'	50'	Fast	Deep	Deciduous, drought tolerant, acorns
Quercus shumardii SHUMARD RED OAK	6'	70'	Moderate	Medium	Deciduous, more drought tolerant than other red oaks
Taxodium distichum BALD CYPRESS	6'	50'	Moderate	Deep	Deciduous, mod. irrigation
Tilia americana AMERICAN LINDEN	6'	50'	Slow to Moderate	Deep	Deciduous, deep rich soil, plenty of water, aphids
Tilia cordata LITTLE LEAF LINDEN	6'	40'	Slow to Moderate	Deep	Deciduous, aphids
Ulmus 'Frontier', 'Prospector' FRONTIER, PROSPECTOR ELM	6'	40'	Fast	Medium	Deciduous, mod. irrigation, Disease resistant
Ulmus parvifolia 'Athena', 'Allee' ATHENA, ALLEE CHINESE ELM	6'	40'	Fast	Medium	Deciduous, mod. irrigation, Frequent pruning
Zelkova serrata 'Green Vase' GREEN VASE ZELKOVA	6'	50'	Moderate	Medium	Deciduous, drought tolerant

**25' DIAMETER TREES**

Shading Calculations: 100% = 491 SQ. FT. 75% = 368 SQ. FT. 50% = 246 SQ. FT. 25% = 123 SQ. FT.

<u>Botanical Name</u> <u>COMMON NAME</u>	<u>Minimum Planter Width</u>	<u>Height To:</u>	<u>Growth</u>	<u>Roots</u>	<u>Remarks</u>
Carpinus betulus EUROPEAN HORNBEAN	6'	40'	Moderate	Medium	Deciduous, densely pyramidal, availability problems
Laurus nobilis SWEET BAY	6'	30'	Slow	Deep	Evergreen, good drainage, drought tolerant
Nyssa sylvatica TUPELO OR SOUR GUM	6'	40'	Slow	Deep	Deciduous, fall color tolerate poor drainage
Pyrus calleryana 'Trinity',	6'	40'	Moderate to	Medium	Deciduous,

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'Chanticleer', 'Redspire' CALLERY PEAR			Fast		flowers
*Umbellularia californica CALIFORNIA BAY	4-6'	25'	Slow	Medium	Evergreen, drought tolerant, deep soil

**20' DIAMETER TREES**

Shading Calculations: 100% = 314 SQ. FT. 75% = 236 SQ. FT. 50% = 157 SQ. FT. 25% = 79 SQ. FT.

<u>Botanical Name</u> <u>COMMON NAME</u>	<u>Minimum Planter Width</u>	<u>Height To:</u>	<u>Growth</u>	<u>Roots</u>	<u>Remarks</u>
Acer buergerianum TRIDENT MAPLE	6'	25'	Moderate	Shallow	Deciduous
Acer campestre HEDGE MAPLE	6'	30'	Slow	Shallow	Deciduous
Acer palmatum JAPANESE MAPLE	4-6'	30'	Moderate	Shallow	Deciduous, fall color, part to full shade
Acer truncatum 'Norwegian Sunset' NORWEGIAN SUNSET MAPLE	6'	30'	Slow	Deep	Deciduous, fall color
Cercis canadensis EASTERN REDBUD	6'	35'	Moderate	Medium	Deciduous, moderate irrigation
Lagerstroemia indica x L. faurei clones CRAPE MYRTLE (Catawba, Cherokee, Pecos, etc.)	4-6'	25'	Slow	Shallow	Deciduous, full sun, mildew, summer flowers
Prunus 'Cascade Snow' CASCADE SNOW CHERRY	4-6'	20'	Moderate	Medium	Deciduous, white flowers, ample water
Prunus cerasifera 'Krauter Vesuvius', CHERRY PLUM	4-6'	20'	Fast	Medium	Deciduous, dark purple leaves, white flowers, fruit
Quercus buckleyi TEXAS RED OAK	6'	30'	Moderate	Deep	Deciduous, fall Color, drought tolerant
Vitex agnus-castus CHASTE TREE	4-6'	20'	Fast	Deep	Deciduous, drought tolerant, flowers
Pyrus kawakamii EVERGREEN PEAR	4-6'	20'	Fast	Medium	Deciduous, white flowers, moderate irrigation.

**Note:** Other tree species may be considered on a case by case basis, subject to the approval of the City Landscape Architect or City Arborist.

\*California native

**APPENDIX B**

**Definitions**

**Amended Soil** - Soil that is brought to the site to enhance plant growth and typically contains approximately 33 percent clay, 33 percent silt and 33 percent sand.

**Clone** - Asexually propagated plants with distinguishing characteristics identical to the parent plant.

**Continuous Planting Island** - Long strips of pervious material that contains trees, shrubs, and ground covers.

**Crown** - The leaves and branches of a tree or shrub; the upper portion of a tree from the lowest branch on the trunk to the top.

**Cultivars** - Seed propagated plants that have certain distinguishing characteristics such as fruitlessness, form and pest/disease resistance.

**Irregular Tree Well** - Tree wells with less than a 6 feet by 6 feet (square) interior dimension.

**Native Top Soil** - Top soil from the construction site. Native soil may not be suitable for growing plants if it has been altered by previous construction.

**Root Barrier** - a tool used to deflect tree roots downward as they grow in order to prevent and mitigate damage to land and hardscapes caused from migrating roots that may uplift streets and sidewalks.

**Rootable Soil Volume** - The volume of soil in and around tree wells and planting islands that tree roots utilize.

**Structural Soil**- Soil mix that is a load bearing matrix of coarse stone aggregate, topsoil, and binding polymer (to bond top soil with aggregate) that can be extended out under asphalt from the tree well to increase rootable soil volume.

**Tree Well** - An isolated planting area for a tree to provide limited soil volume for tree roots and rainfall infiltration.