

Bridging the gap between intention and execution:
Effective tree planting practices in Manhattan, Kansas

by

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A REPORT

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Abstract

Trees provide ecological, social, health, and economic benefits in urban and suburban environments. These include stormwater management, improved perception of safety, shade, and carbon sequestration. The realization of these benefits is contingent on trees growing to their full maturity and the overall wellness of trees. Tree planting ordinances in urban design often call for a certain number of trees for each new development, but design practices and the maintenance needed to keep trees alive often fall short. Young, vulnerable trees planted in harsh environments may only survive a few years past planting, while large, established trees are removed from sites to make way for future development. As trees die due to their surrounding conditions, projected benefits—why they were required and planted—are foregone completely and cities fall short in reaching climate action goals and creating healthy living environments.

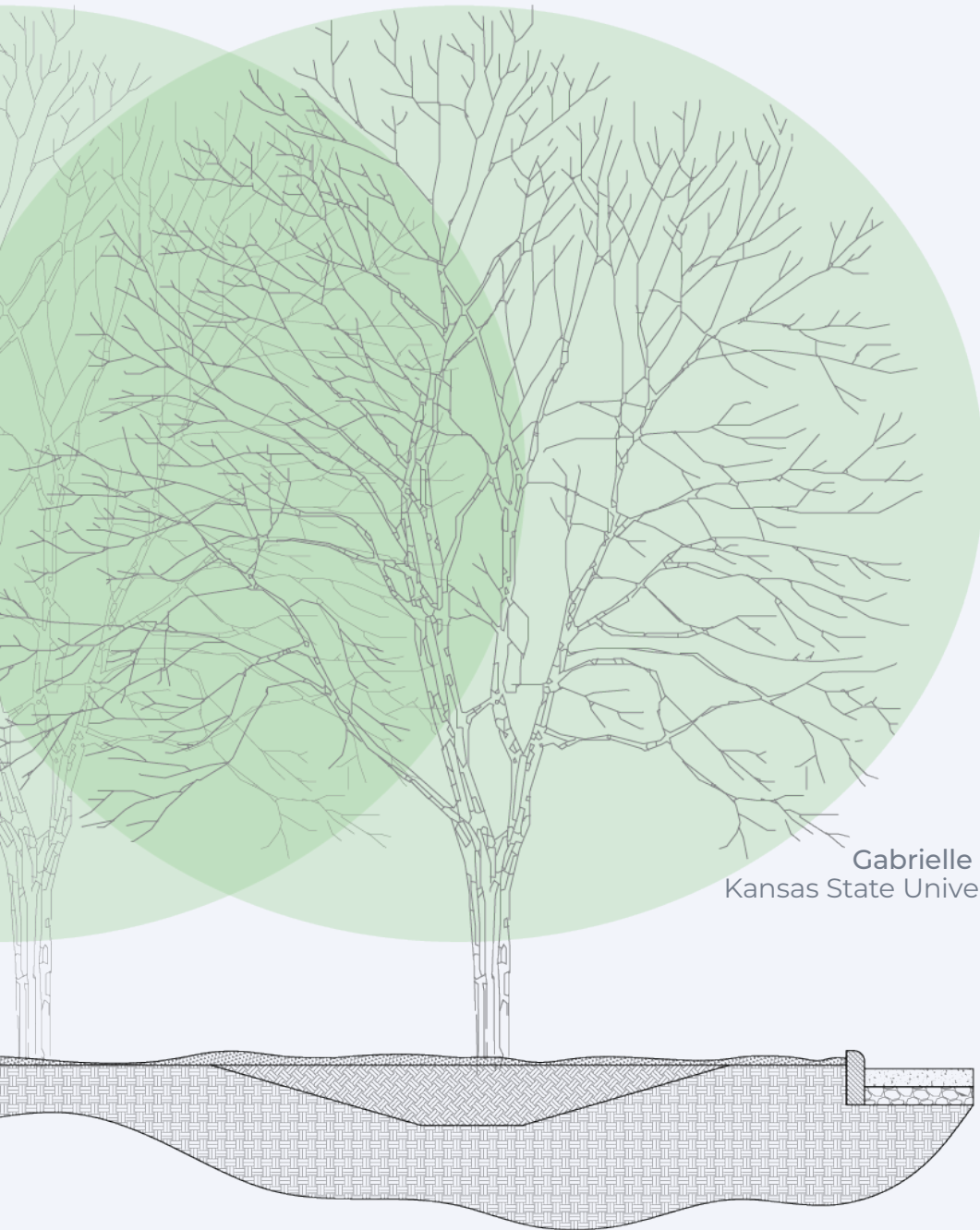
Insufficient attention is being paid to the implementation and maintenance strategies needed to keep the trees alive and thriving — past the establishment period — in order to actualize their benefits. This study aims to identify those strategies, and how to implement them effectively as high-density residential zoning districts densify from single-family homes to multi-family complexes. Several methods were used to answer the following question: As two sites in Manhattan, Kansas are densified, how can street trees be implemented and maintained to maximize their longevity and receive the full benefits they can provide, based on their contextual and biophysical conditions? Three precedent study reviews are followed by an analysis of residential blocks that have experienced densification and significant tree loss in the last 10 years. Projective designs show how innovative planting strategies can be applied to two sites.

Planting design guidelines for future development, including site design essentials, tree planting drawings, and required implementation and maintenance strategies, will help ensure tree

health past the establishment period. Design guidelines applied to two sites in Manhattan, Kansas (which have yet to be densified, but have a potential to be based on their zoning classification and contextual patterns of the neighborhoods they belong to) will help the City of Manhattan and Kansas Foresters as they review development proposals. This study builds upon past research and practices to identify when specific planting design, implementation, and maintenance strategies must be applied, and provides a framework that can be used in Manhattan, Kansas and other densifying urban landscapes.

Bridging the Gap Between Intention and Execution:

Effective Tree Planting Practices in Manhattan, Kansas



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Kansas State University 2024

Bridging the Gap Between Intention and Execution:

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Abstract

Background

Trees provide ecological, social, health, and economic benefits in urban and suburban environments. These include stormwater management, improved perception of safety, shade, and carbon sequestration. The realization of these benefits is contingent on trees growing to their full maturity and the overall wellness of trees. Tree planting ordinances in urban design often call for a certain number of trees for each new development, but design practices and the maintenance needed to keep trees alive often fall short. Young, vulnerable trees planted in harsh environments may only survive a few years past planting, while large, established trees are removed from sites to make way for future development. As trees die due to their surrounding conditions, projected benefits—why they were required and planted—are foregone completely and cities fall short in reaching climate action goals and creating healthy living environments.

Purpose and Methods

Insufficient attention is being paid to the implementation and maintenance strategies needed to keep the trees alive and thriving — past the establishment period — in order to actualize their benefits. This study aims to identify those strategies, and how to implement them effectively as high-density residential zoning districts densify from single-family homes to multi-family complexes. Several methods were used to answer the following question: As two sites in Manhattan, Kansas are densified, how can street trees be implemented and maintained to maximize their longevity and receive the full benefits they can provide, based on their contextual and biophysical conditions? Three precedent study reviews were followed by an analysis of residential blocks that have experienced densification and significant tree loss in the last 10 years. Projective designs showed how innovative planting strategies can be applied to two sites.

Expected Outcomes

Planting design guidelines for future development, including site design essentials, tree planting drawings, and required implementation and maintenance strategies, will help ensure tree health past the establishment period. Design guidelines applied to two sites in Manhattan, Kansas (which have yet to be densified, but have a potential to be based on their zoning classification and contextual patterns of the neighborhoods they belong to) will help the City of Manhattan and Kansas Foresters as they review development proposals. This study builds upon past research and practices to identify when specific planting design, implementation, and maintenance strategies must be applied, and provides a framework that can be used in Manhattan, Kansas and other densifying urban landscapes.

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Introduction

Introduction

Dilemma

Significant tree canopy loss has been noted in Manhattan, Kansas, and is particularly present in the Urban Core Residential (RC) and High Density Residential (RH) development zones as these areas have experienced dramatic development changes in the last 10 to 20 years. To continue receiving the benefits provided by street trees, changes must be made to the design implementation, and maintenance practices that contribute to their mortality.

Importance

According to Kuo (2003), trees can be regarded as essential infrastructural elements, not just aesthetic amenities (Kuo 2003, 153). This means that planning organizations, governmental institutions, and designers have a responsibility to allocate resources to ensure the health and longevity of street trees in order to maximize the benefits promised to be received by community members.

Knowledge of best practices and application of this information during site design and implementation will help ensure tree growth, and thus actualize the benefits of urban and suburban street trees. It is important to note that landscape architects must employ the knowledge and expertise of urban foresters, planners, soil scientists, engineers, architects, horticulturists, and other professionals to achieve these goals.

Research Question

As two sites in Manhattan, Kansas are densified, how can street and site trees be designed for and implemented to maximize their longevity and receive the full benefits they can provide, based on their contextual and biophysical conditions?

Sub-Questions

- 1 How has densification in the last 10 years impacted High-Density and Urban Core Residential zones in Manhattan, Kansas?
- 2 Which physical conditions present in the study area contribute to street tree mortality? Which are the most prominent?
- 3 What are the current zoning/design guidelines regarding street trees in Manhattan, Kansas? Where can they improve to better ensure tree longevity?
- 4 What are the specific tree selection and planting strategies needed to ensure tree longevity? What contexts should they be applied in?

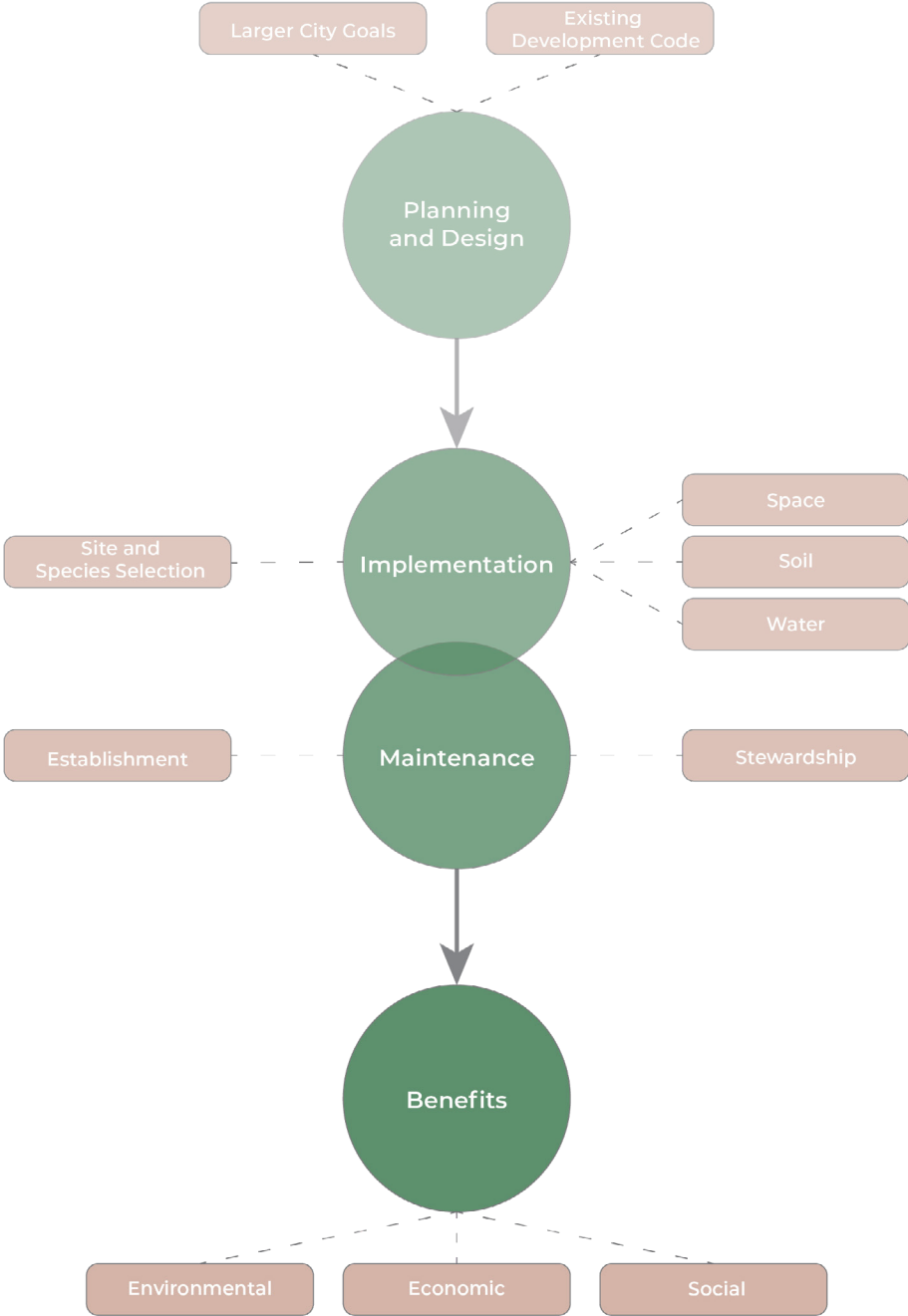


Figure 1.1 Project Overview (Saunders 2023).

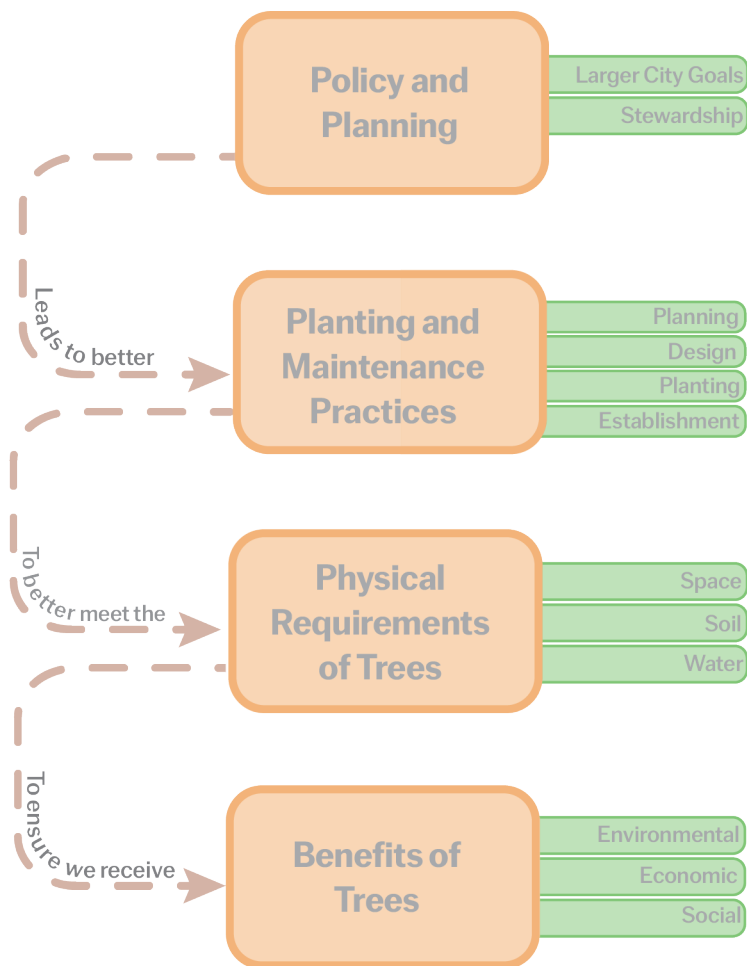


Figure 2.1 Literature Map (Saunders 2024).

Benefits of Trees

Benefits of Trees in Urban Areas

Street trees have been found to have quantifiable, transferable benefits to the neighborhood fabric and surrounding community (Figure 2.2). These benefits can be categorized as: **Environmental** (stormwater management, shade, carbon sequestration, biodiversity), **Economic** (increased property values, reduced energy costs), and **Social** (safety perception, use of space, sociability). According to Jack-Scott (2011): “Crown fullness and size are often positively correlated with these benefits; larger, fuller trees generally produce greater effects” (Jack-Scott 2011, 1).

Environmental

Trees “play an important role in the urban water cycle, their canopies intercepting rainfall and modifying runoff [thus] reducing demands on conventional stormwater infrastructure” (Ely 2009, 16).

Certain species of mature trees can manage the rainwater of between 5,000 and 10,000 square feet of impervious surfaces (Urban 2007, 2). In suburban contexts with large driveways and wide roads, this is an important aspect to consider.

In a study by McPherson (2001), it was found that Sacramento’s tree canopy sequestered 74 tons of carbon dioxide per year (McPherson 2001, 109). As a result of healthy street trees and urban forests, air quality is improved and pollution is reduced in an age where automobiles are central to urban living (Ely 2009, 16).

Additionally, mature tree crowns can prevent up to 95% of solar radiation, decreasing heat, and providing comfort and increased health to people who use outdoor spaces (Milošević et al. 2017, 113). The tree crown and trunk also provide habitat to wildlife, creating “a more hospitable setting for many species” (Kuo 2003, 148).

Economic

When trees fulfill their environmental benefits, they also increase economic values. The Urban Forests Effects (UFORE) modeling tool “quantified the value of total air pollution removal from the urban forest in California at \$136,800,800” (Pincetl et al. 2012, 479). However, these metrics are contingent on healthy, mature trees, a feat proving difficult to achieve in some communities.

Social

According to James Urban: “Healthy, long-lived trees also contribute to the social and economic health of urban communities” (2007, 1). Trees, as well as overall green space, increase usage of outdoor spaces by both adults and children, and improve sociability between neighbors and community members (Kuo 2003, 152). Additionally, contrary to some who believe that trees block views and therefore decrease safety, wisely located trees and greenery greatly improve the perception of safety and desire to be in an outdoor space. This is as opposed to unkempt, vacant land (Kondo 2016, 3281) or locations where trees and/or vegetation block site lines to traffic and pedestrians.



Figure 2.2 Diagram of Urban Tree Benefits (Saunders 2023).

Physical Requirements of Trees

Biophysical stressors like compacted soils, impervious hardscape, and insufficient water “are to be expected given that cities are highly engineered environments built by and for humans” (Breger et. al. 2019, 1). In a study cited by Ow et. al. (2018), trees in urban areas lived 50% shorter lives than trees in more naturalized sites. In environments dominated by impervious surfaces like concrete and asphalt, increasing tree canopy cover in urban areas presents a challenge, as street trees are more vulnerable to death, and may never reach full maturity (or provide maximum benefits) unless designed and maintained to meet the physical requirements for any specific species of tree (Berland 2012, 735; Coder 2000, 1; McPherson 2001, 118; Steenberg et. al. 2017, 116).

Therefore, it is especially important to understand what a tree may require. In his book “Up By Roots”, James Urban outlines three major requirements for tree survival: **space**, **soil**, and **water** (2008).

Space

There is a notable pattern of street trees planted in small sidewalk cutouts near roads, driveways, and sidewalks. The traditional very small cutout of planting space (sometimes less than 30 cubic feet) is not adequate for tree growth and survival (Lu et. al. 2010, 10; Nowak et. al. 1990, 129; Steenberg et. al. 2017) and can limit tree life to just 10 years (Watson et. al. 2014, 259). In fact, “a large tree needs more than 1,000 cubic feet of soil to reach the size where it becomes a significant contributor to a healthy urban ecosystem” (Urban 2007, 1). Proximity to infrastructure also plays an important role, as excessive pruning can result from proximity to power lines, which adds more stress and vulnerability to impacted street trees (Steenberg et. al. 2017, 119).

Soil

For trees to survive and thrive, the soils they are planted in must be the correct porosity, nutrient level, and uncompacted (Urban 2007, 1). When soil becomes compacted “roots will be concentrated around the edges of infrastructure and filling any moist air space” (Coder 2000, 1). This can lead to damage to the surrounding hardscape. Additionally, contaminants such as auto fluids, salts, and heavy metals can greatly stunt the growth of a tree, and even cause death (Steenberg et. al. 2017, 120).

Water

While excessive irrigation can cause problems later in life for a tree, healthy trees should not typically need frequent irrigation (Watson et. al. 2014, 261). Stress is typically seen in trees because of a lack of water for very young or non-drought-tolerant species during periods of drought where no supplemental water is provided (Craul 1999, 227).

Tree Planting and Maintenance Practices in the U.S.

Trees are recognized as infrastructural components to sustainable urban design (Steenberg et. al. 2017, 115). As a result, cities like New York, Los Angeles, Indianapolis, and other municipalities around the U.S. are investing in tree planting, including species selection and diversification strategies (Nitoslawski et. al. 2017, 188). However, “urban street tree counts continue to decrease, and funding availability remains the greatest challenge facing tree planting efforts” (Jack-Scott 2011, 1).

Continued investment must be made in their long-term survival, and site-specific, small-scale efforts -- such as staking, irrigation, species selection, soil amendments, adequate space -- are essential to actualize the potential benefits of street trees (Lu et. al. 2010, 2; Nitoslawski et. al. 2017, 188).

Larger City Goals

While many cities have focused on tree planting, investment in tree health and longevity, as well as community involvement, must be prioritized. Many leaders are striving for stronger communities, reduced crime rates (Kuo 2003, 153), and combatting noise issues, carbon pollution, erosion, and habitat loss (Petri et. al. 2016, 101). While these are high-level aspirations, trees can help provide these benefits to whole communities, and should be frequently discussed to encourage community support for ongoing renewal and care of urban forests.

Policy and Planning Requirements

With problems to solve, and trees being an important part of the solution, policy must be the vehicle. Many planning policies, including Manhattan, Kansas’ codes and standards, merely require that trees be planted. The major gaps include tree protection, responsible and thoughtful planting requirements, and care through establishment. In a study conducted on the Million Trees Los Angeles program, 67% of the trees planted did not survive, with 34% of them dying within two years of planting (Petri et. al. 2016, 109). In situations like this, focusing on the planting and care of existing trees becomes more important than planting new ones, and that should be reflected in the city’s policy. Manhattan, Kansas has a rich canopy of mature trees but they are being removed at high rates due to construction, and a general lack of maintenance. This mature canopy should not be replaced by young trees planted in harsh conditions, without the requirement that they live for at least five years (and hopefully, with ongoing stewardship,

more than 40-50 years). Therefore, stricter, more detailed policy is much needed in Manhattan, and across many cities in the United States.

Planning policy and thinking for the future can greatly reduce tree mortality on a large scale. For example, adjacent construction efforts alone can damage a large amount of trees. In a study done by Hauer et. al. (1994), Milwaukee’s loss of 6,000 trees a year due to construction damage amounted to “a loss of approximately \$521,500 per year in tree value” (Hauer et. al. 1994, 96). Implementing tree protection policies to prevent construction damage could decrease mortality rates in trees. Additionally, Breger et. al. found that trees receiving maintenance and stewardship by state agencies in Holyoke, Massachusetts, had a survival rate of 88.5%, as opposed to trees that were left solely to residents, which had a survival rate of 59.2% (Breger et. al. 2019, 6). This finding highlights the need for a strong relationship between governing institutions and community members.

Tree Planting and Maintenance Practices in the U.S.

Stewardship

When addressing street trees adjacent to private property, it is exceedingly important to gain support from homeowners and community members within the project area. When costs and responsibility for tree planting and care are solely assigned to homeowners, support and willingness decrease. However, the availability of subsidies, low-cost materials, and education of community members can greatly increase participation (Conway and Bang 2014, 241). Since trees stewarded by owners alone don't typically remain healthy (Breger et. al. 2019, 8), there is an opportunity for collaboration between cities, towns, responsible institutions, and private landowners to make progress toward easy, ongoing, and modest tree stewardship.

Not only can homeowners be willing to participate in greening efforts, but they can be incredibly useful resources where planning organizations fall short. In a study done in partnership with Friends of Greenwich Street, Boyce (2010) found that “expanding the definition of tree stewardship to include trained volunteers, stewards who can simply ‘walk around’ and recognize threats to the street trees can pay large benefits, if, and only if, such “observational tree stewardship is coupled with rapidly engaged professional tree rescue resources” (Boyce 2010, 7). When tree planting initiatives led by state, county, or local agencies are developed and implemented in partnership with willing and able community members, stewardship of the suburban tree canopy is feasible and effective.



Figure 3.1 Diagram of Methods and their Deliverables (Saunders 2024).

After reviewing the literature and defining the deliverables of design standards and projective design, four methods were used together to answer this question: As two sites classified in Urban Core Residential and High-Density Residential zones in Manhattan, Kansas are densified, how can street trees be selected and implemented full environmental, social, and economic benefits they can provide, based on their contextual and biophysical conditions?

The first method, **precedent studies**, focused on the comprehensive plan for Oklahoma City, Oklahoma, streetscape design standards from Bethesda, Maryland, and New York City’s Site Assessment Tool for young street trees. The second method, **develop a street tree-focused site assessment tool for future development and maintenance**, guided site analysis.

Imagery of ten sites in the “Urban Core Residential” and “High-Density Residential” zones in Manhattan, from Google Earth and ArcGIS Pro, was collected and analyzed, comparing tree canopy coverage, impervious surfaces, and dwelling units in 2012 versus 2022. Then, six of the ten sites were evaluated using an adaptation of New York City’s Site Assessment Tool.

The third method, **develop planting design guidelines for Manhattan, Kansas developers, property managers, and homeowners**, provide standard planting details and practices that will guide future development and densification in Manhattan, Kansas. Lastly, **projective designs** were developed for two selected sites, responding to existing trends found in the project area, and applying the developed guidelines.

Site Selection and Analysis of Overall Project Area

Sites in Manhattan were chosen based on the following three factors to narrow down the selection to ten sites: 1) The site is located under High-Density Residential and Urban Core Residential zones, 2) the site has been densified through development in the last ten years (recent development was the most relevant to the current development code, but a ten-year difference allows for adequate differences), and 3) the site has experienced site tree loss due to this development. Within a 26-block project area (Figure 3.2), ten sites were found to meet these criteria. On these sites, a table adapted from New York City’s Site Assessment Tool was used to conduct site analysis given its quality and ease of use.

Criteria from the Site Assessment Tool was selected and/or modified based on the relevance to this region and project, and to allow for easy on-

site analysis without complex processes or tools. The data found from Site Analysis was recorded and organized to reveal the most pressing factors related to tree mortality in Manhattan, Kansas.

Unless they are immediately adjacent to a high-density-zoned half-block, areas zoned for low- and medium-density residential developments are not considered in this study for two reasons. First is the status of tree canopy. Most new, low to medium density single-family developments near Manhattan, Kansas are placing trees in areas where trees were not previously growing, as the natural environment was historically tallgrass prairie. Therefore, the tree canopy is increasing, not decreasing. Second, low to medium density single-family residential areas are not experiencing a pattern of further densification beyond single-family housing.

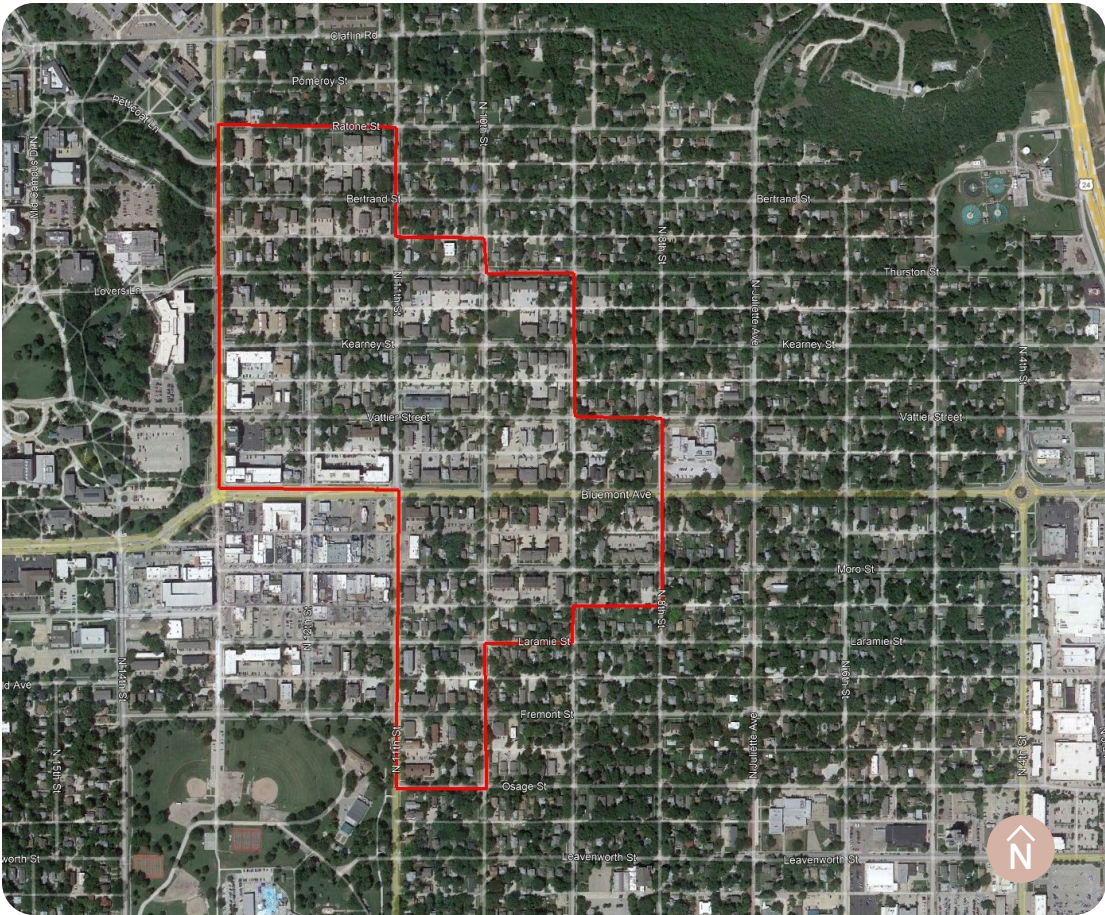


Figure 3.2 Manhattan Project Area (Saunders 2024).

Precedent Studies

Three precedents were chosen to aid in different stages of this research project. The first stage, Site Analysis, includes an overall assessment of the project area, and a detailed tree-focused site assessment. The second stage is the development of standard drawings for future high-density developments in Manhattan, Kansas, which includes suggestions for policy changes as well as standard planting drawings to be used in future landscape plans. The third and last stage, projective design, involves applying the developed guidelines to two selected sites in the project area.

First, the New York City Site Assessment Tool assists in site analysis and projective design, providing evaluation criteria that are easy to understand and use to collect important data.

The second precedent, “Putting Down Roots,” developed by Oklahoma City’s planning commission, provides guidance on regional conditions, site selection, and rules for planting methods and maintenance practices in Oklahoma City. This precedent influenced the development of a planting design manual specific for Manhattan, Kansas, and guided projective design. The last precedent, Bethesda, Maryland’s Streetscape Standards, provides an example for standardized tree planting design in an urbanizing area. Started by James Urban in the 1980’s, and continued by the city today, these drawings provided a visual precedent for the planting design manual.

PlanOKC: Oklahoma City's "Putting Down Roots"	Bethesda, Maryland Streetscape Standards	New York City Street Tree Assessment Tool	
Helped to develop standard drawings for future high-density developments in Manhattan, Kansas; Guided Projective Design	Helped to develop standard drawings for future high-density developments in Manhattan, Kansas; Guided Projective Design	Site Analysis; Guided Projective Design	Applicability
"Putting Down Roots" provided guidance on regional conditions, site selection, and rules for planting methods and maintenance practices in Oklahoma City.	Bethesda provided an example for standardized tree planting design in an urbanizing area, as well as best maintenance practices.	This survey is an evaluation tool for the health and maintenance needs of street trees, and can be used by any professional or community member	Importance
Informed the creation of the manual for Manhattan, Kansas, and showcased the relationship between landscape architects and other professionals in the civic realm	Applications of James Urban's principles informed the creation of the standard drawings based on surrounding conditions, and served as visual inspiration	This tool was adapted to complete an analysis of each of the selected sites in Manhattan, Kansas	Project Stage

Figure 3.3 Precedent Applications (Saunders 2024).

Study Area Analysis

Before an in-depth site analysis occurred for the sites selected, shown in Figure 3.2 based on the criteria covered on page 30, factors outlined in Table 4.1 from past and current imagery from Google Earth and ArcGIS Pro (Figures 3.5 and 3.6) was compared. Impervious surface coverage, tree canopy coverage, and dwelling unit counts were measured for each site, and the results for each site are discussed in Chapter 4 of this document. The process to measure the three factors were each slightly different.

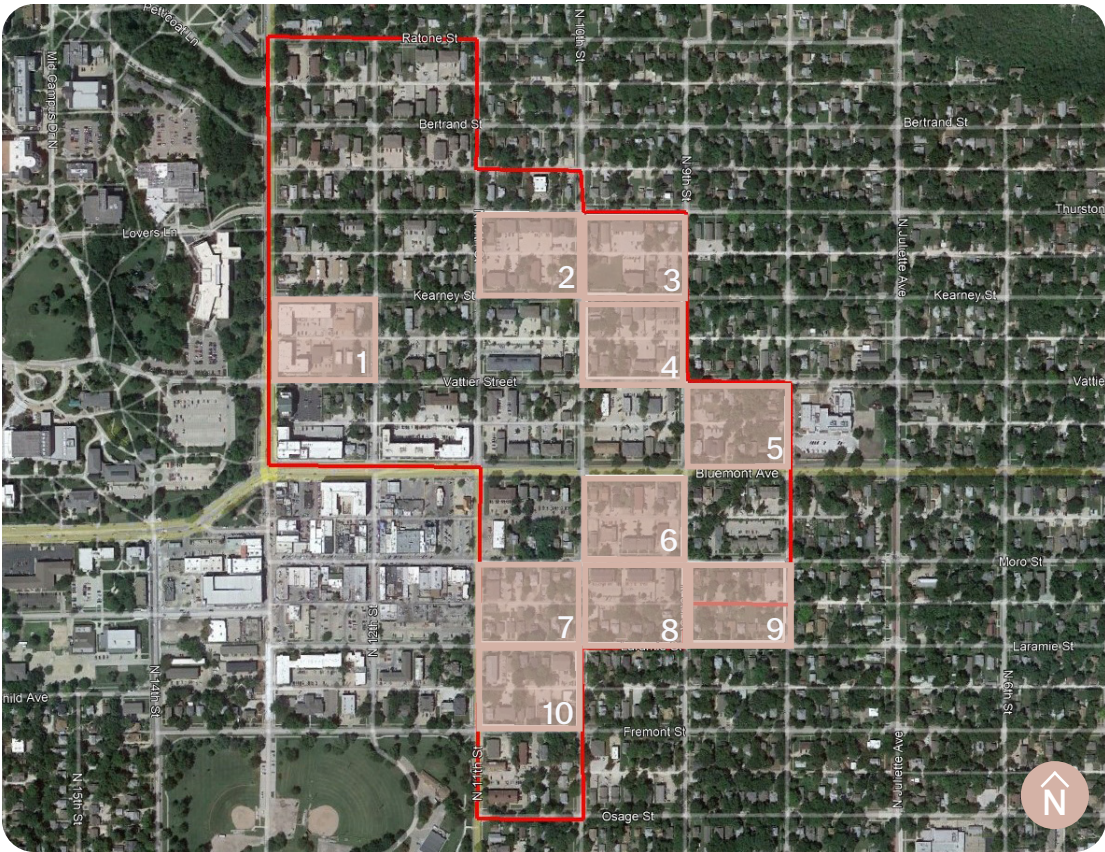
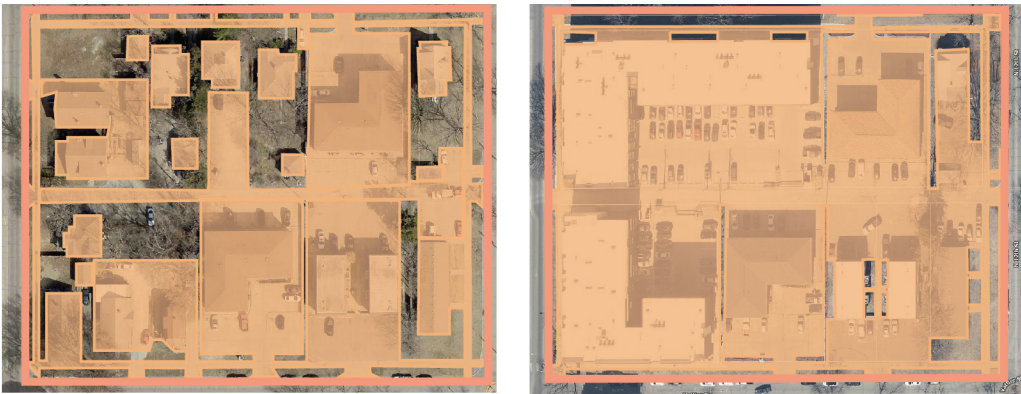


Figure 3.4 Map of selected sites within the Project Area (Saunders 2024).

Figure 3.5 Impervious Surface measurements for Site One in 2012 (left) and 2022 (right) (Saunders 2024).



Impervious Surfaces

To measure and compare the percentage of impervious surfaces over time, satellite imagery from 2013 obtained from Riley County was imported into ArcGIS Pro. This imagery is specifically taken in the winter so the ground underneath tree canopies can be viewed, which is something the use of Google Earth cannot guarantee. Screen captures were taken from the GIS geodatabase and externally referenced into an AutoCAD file. For each site, the boundary was

defined by the front of curb, and nothing outside the boundary was counted. Edges of buildings, sidewalks, driveways, and gravel parking lots were outlined and then hatched to find the total area of impervious surface. The total site area, and total impervious surface coverage was recorded for each site in 2012, and in 2022: twenty diagrams in total were prepared and then analyzed. The comparison for Site One is shown in Figure 3.5.

Tree Canopy Coverage

Summer imagery was taken from Google Earth Pro to measure the coverage provided by the tree canopy on each block. Again, screen captures were taken and externally referenced to AutoCAD. The block boundaries were the same, from front of curb to front of curb. The canopy was not measured over the street itself, to maintain consistency. Like impervious surface measurements, total area of tree canopy for each site was found from measurements made on the twenty site diagrams, recorded from 2012 imagery, then 2022 imagery (Figure 3.6).



Figure 3.6 Tree Canopy Coverage measurements for 2012 (left) and 2022 (right) on Site Two (Saunders 2024).

Dwelling Units

To find the number of dwelling units on each of the blocks, information from two different sources was used. For data from 2013, the same ArcGIS Pro geodatabase was used as the data for impervious surface imagery. For 2022, Riley County GIS provides the same information for current dwelling units on their public website (CITE). The dwelling units for each lot on each block were recorded and added to find overall sums for each block and compared by year.

Using a Street-Tree Focused Site Assessment Tool for Future Development

To support the site analysis for the selected sites, a matrix (Table 3.1) was used to evaluate the “Tree Health Indicators” of each street tree within the selected 10 blocks. This tool was adapted for this study from the Site Assessment Tool employed by New York City, which is designed to allow citizens (with training) to evaluate street tree conditions without advanced tools or detailed construction drawings. For the sake of time, some factors from the tool were omitted from this study based on their lack of relevance to the study area, or the inability of the author to collect that data. For example, ‘evidence of leaf chlorosis’ would not have been possible to record, because the analysis was conducted in the winter.

Additionally, data like ‘soil compaction’ and ‘planting depth’ were not within the ability of the author to measure and record and were therefore omitted. The responses to the criteria were recorded for each tree, while visiting each site (block), using a Google Form, along with written notes. The Google Form is programmed to automatically organize the responses to each criterion by producing pie charts, graphs, and other graphics. For example, after completing site analysis, tree species (the first criteria measured) is represented by a pie chart, and the most common response is readily visible. This data reveals patterns that need to be addressed through the planting design manual and projective design (e.g., a large portion of sidewalks in poor condition, tree pits consistently too small, etc.).

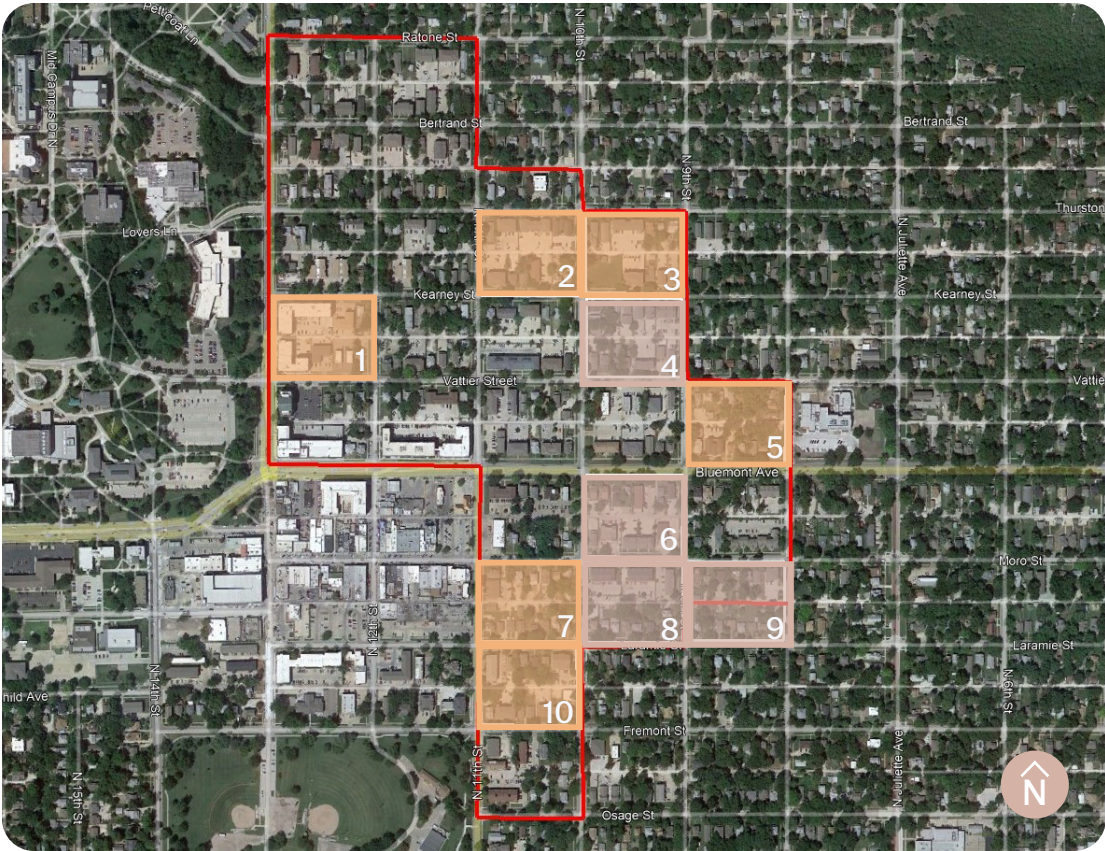


Figure 3.7 Site Assessment Selection (Saunders 2024).

Tree Health Indicators		Response (with notes as needed)
Biological Factors		
Species of tree	botanical name	
Height of tree and DBH (diameter at breast height)	estimated height (ft); DBH (in.)	
Trunk wounds or signs of suckers/shoots	yes/no - note conditions	
Unnatural lean	yes/no - note angle of lean	
Guard, wire, or grate girdling tree	yes/no - note conditions	
Signs of water pooling in the tree pit	yes/no - note conditions	

Physical Conditions Near Each Tree		Response (with notes as needed)
Tree pit type	bed, lawn, median, pot, etc.	
Tree pit size	sq. ft.	
Tree pit distance from curb	inches	
Tree grate	yes/no	
Curb condition	description	
Sidewalk condition	description	
Tree proximity to built structure	ft. from building facade	
Number of adjacent building stories	number of stories/floors	
Sidewalk width near tree trunk	ft.	
Stakes and/or wiring present	yes/no - note conditions	
Tree pit paved to tree trunk	yes/no - note type of paving	
Mulch in tree pit	yes/no - note type and depth	
Gravel in tree pit	yes/no - note type and depth	
Evidence of weeds or debris in tree pit	yes/no - note type	
Evidence of pruning	yes/no - note any concerns	
Lights in or around tree	yes/no - note any concerns	

Table 3.1 Site Assessment Matrix (Saunders 2024)

Develop Standard Planting Guidelines for Manhattan Developers, Property Managers, and Homeowners

After assessing the conditions of trees on the chosen sites in Manhattan, Kansas, design guidelines (inspired by those of Bethesda, Maryland, and Oklahoma City) for soil preparation and planting practices were developed to alleviate the potential issues contributing to tree mortality in Manhattan, such as infrastructure conflicts, heavy pruning, and a lack of quality soil space. The next step was to define specific implementation strategies and practices that should be used by developers and designers for future developments. These implementation strategies and practices specifically apply to street and site trees on new developments where a tree is removed during or after construction.

The information in the manual includes specific space, soil, and water needs for proposed trees in various conditions. If these needs cannot be met by the proposed design (e.g., not enough space), then the manual suggests design implementation solutions (e.g., root trenches). These solutions are presented in the form of standard drawings that can be included in future construction documents. The need for intentional and informed species selection is mentioned in the manual, and resources were given, but extensive details for specific plant species needs are not provided in the manual. Additionally, while detailed maintenance plans and community involvement are necessary for the success of these methods, and are briefly covered, development of a detailed maintenance and community involvement plan is beyond the scope of this report. This method answers several sub-questions, addressing specific design implementation strategies, and where the existing zoning code in Manhattan, Kansas can improve.

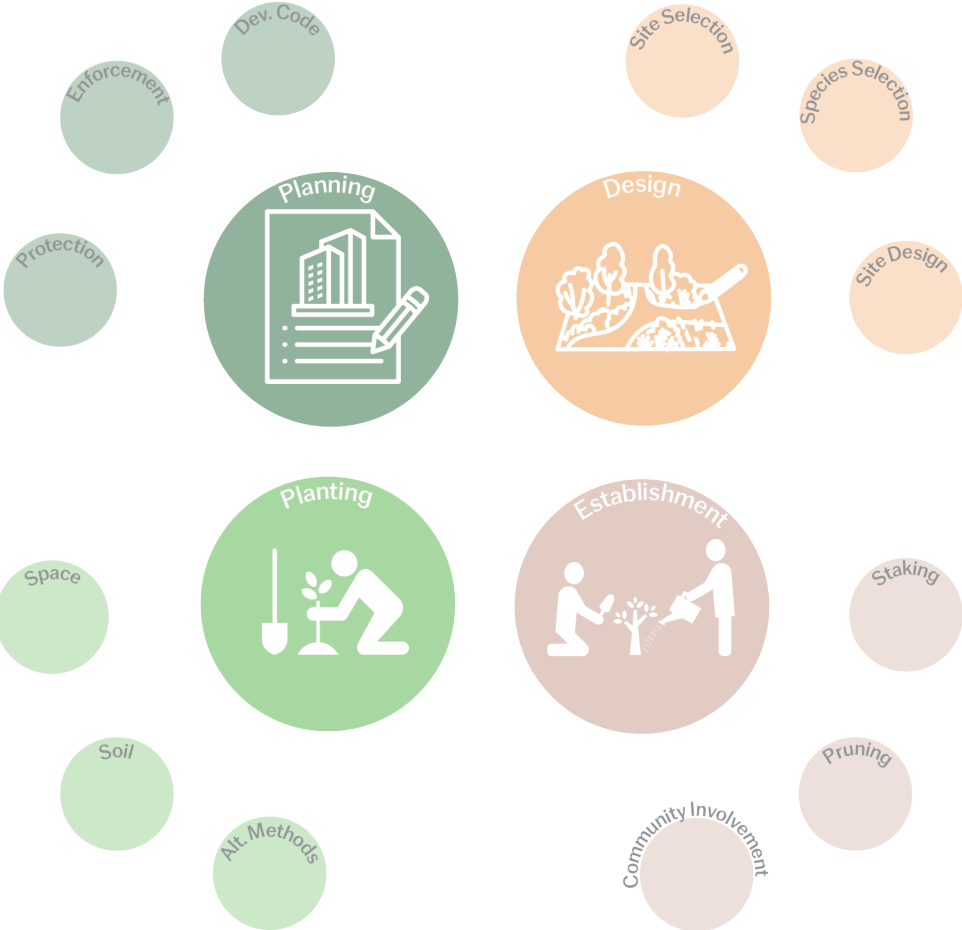


Figure 3.8 Diagram of Guideline Topics (Saunders 2024).

Projective Design

After the site assessment revealed major issues to be addressed, and guidelines were developed to help resolve the issues, two sites in the project area were selected based on the fact that 1) they have not experienced densification in the last ten years (but have the potential to based on their zoning classifications), and 2) they have not experienced major tree canopy decreases. A conventional design is proposed for each site by projecting the existing trends to show what the current conditions of site design and tree planting would be in Manhattan, Kansas, assuming current policies, standards, oversight, design, development, implementation, and enforcement. For example, if an average loss of six trees per site was found in the project area, then six trees were removed in this baseline design. This design, along with the alternative design integrating the guidelines developed in this project, were projected for ten years from 2024 to allow for consistent and accurate tree canopy coverage representation.

Additionally, trends found in the process of site analysis reveal the needs to be addressed in each proposal (e.g., maximizing space, amending soils, and avoiding buildings and power lines). The developed design guidelines were then followed during the design process and reveal the benefits of those guidelines. All these processes have informed projective design proposals on the selected sites with the aim of guiding future densification and development, while ensuring that newly planted trees will survive the increasingly harsh conditions of high-density residential developments in Manhattan, Kansas. This process has helped to answer my primary question of how street trees can be chosen and implemented to maximize longevity and benefits past the establishment phase.

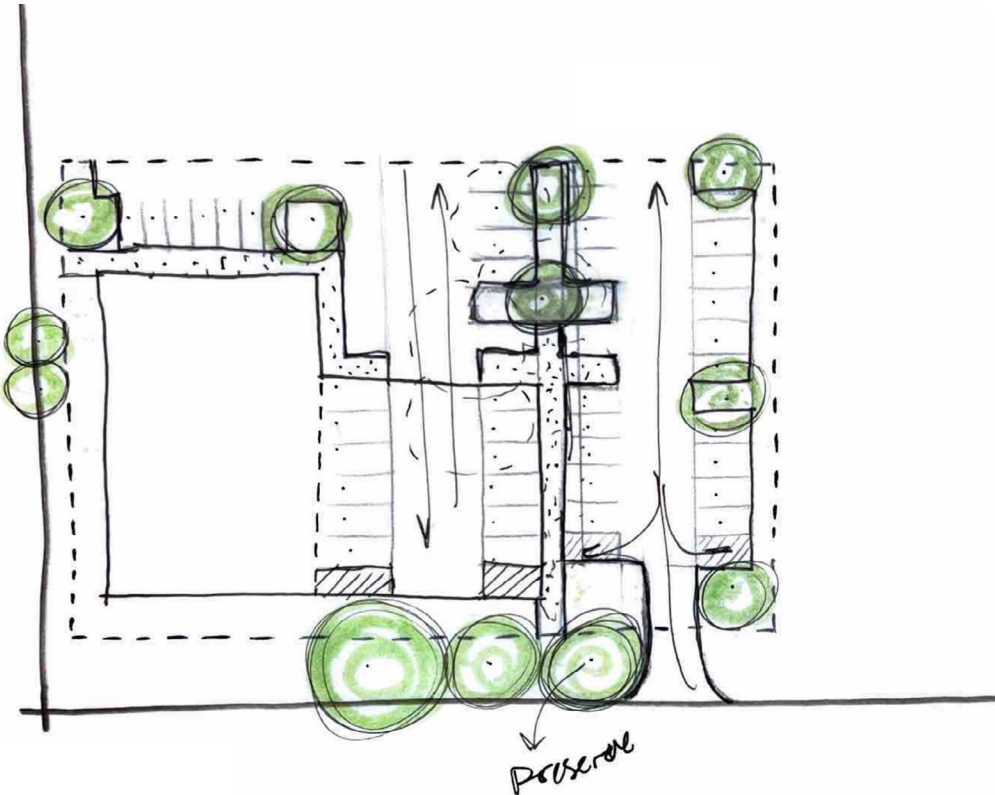


Figure 3.9 Process Sketch (Saunders 2024).

4

Findings

Study Area Analysis: 2012 and 2022

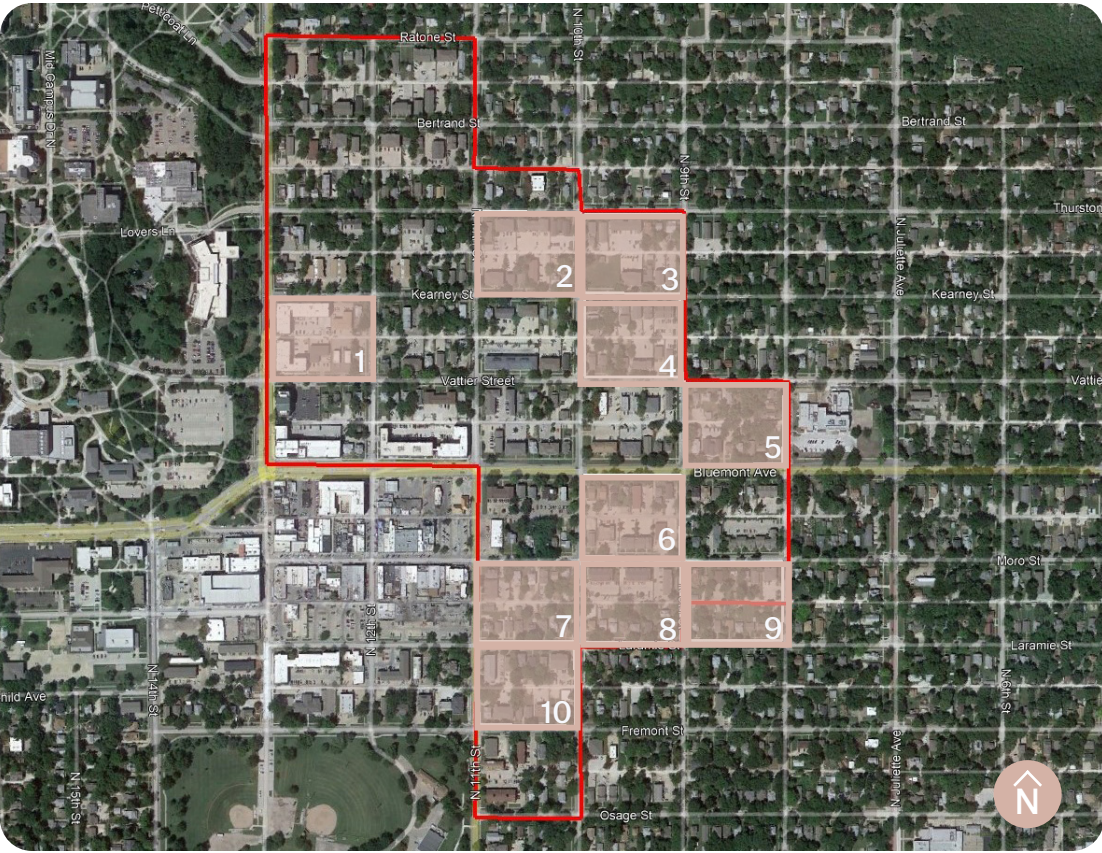


Figure 4.1 Site Selection within 26-block Project Area (Saunders 2024).

Before the detailed tree assessment was conducted, an analysis of the overall study area (26 blocks) was conducted to find and confirm trends of urban development densification and tree canopy loss for the 10 selected sites. Google Earth Imagery was used for the measurement of tree canopy coverage for both 2012 and 2022. Imagery and lot information were obtained from Riley County GIS to measure the percentage of impervious surface coverage and number of dwelling units. The Riley County GIS website and an archived geodatabase with information from 2013 were used for this analysis as follows:

Computer screen captures from GIS databases and Google Earth were imported into AutoCAD and traced to find the percentage of tree canopy coverage and percentage of impervious surface coverage. These percentages were recorded and revealed patterns related to the loss of tree canopy coverage in the project area, and the densification of the Urban Core Residential (RC) and High-Density Residential (RH) zones. Table 4.1 shows how the results from the analysis were recorded, and Table 4.2 shows the results from each site.

Site X	2012	2022
% Tree Canopy Coverage		
% Impervious Surface		
# Dwelling Units		

Table 4.1 Study Area Analysis table (Saunders 2024).

Site 1	2012	2022
% Tree Canopy Coverage	32%	8%
% Impervious Surface	56%	84%
# Dwelling Units	55	124
Site 2	2012	2022
% Tree Canopy Coverage	30.5%	19%
% Impervious Surface	54%	58%
# Dwelling Units	41	79
Site 3	2012	2022
% Tree Canopy Coverage	29%	15.5%
% Impervious Surface	54%	58%
# Dwelling Units	37	44
Site 4	2012	2022
% Tree Canopy Coverage	31%	24%
% Impervious Surface	55%	64.5%
# Dwelling Units	40	47
Site 5	2012	2022
% Tree Canopy Coverage	36.5%	33.5%
% Impervious Surface	36%	42.5%
# Dwelling Units	29	42

Table 4.2 Study Area Analysis Results for each site (Saunders 2024). Note: Percentages for tree cover and impervious surfaces were rounded oto the nearest 0.5%. Totals do not equal 100%.

Site 6	2012	2022
% Tree Canopy Coverage	27.5%	15.5%
% Impervious Surface	66%	69%
# Dwelling Units	64	66
Site 7	2012	2022
% Tree Canopy Coverage	22%	24%
% Impervious Surface	55%	54.5%
# Dwelling Units	44	44
Site 8	2012	2022
% Tree Canopy Coverage	33%	24%
% Impervious Surface	59%	61%
# Dwelling Units	20	52
Site 9	2012	2022
% Tree Canopy Coverage	28%	25%
% Impervious Surface	38.5%	44%
# Dwelling Units	31	30
Site 10	2012	2022
% Tree Canopy Coverage	26%	26%
% Impervious Surface	50.5%	57.5%
# Dwelling Units	48	61

33% Decrease

In Overall Tree Canopy Coverage

Percentage of Tree Canopy Coverage

Across all ten sites, there was an average loss in tree canopy coverage of 33% between 2012 and 2022. The most dramatic change occurred on Site One, with a 76% decrease in coverage. However, two sites presented outliers. Site

Seven experienced a 9.5% increase in canopy, the only site in the project area to do so. Site Ten experienced no change at all in the canopy coverage, presenting another unique situation.

Percentage of Impervious Surface

Across the analyzed sites, there was an average increase in impervious surfaces of 8.5%. Every block except Site Seven experienced an increase, ranging from 3.5% (Site Eight) to 33% (Site One). Site Seven showed a negligible decrease of 0.5%, solidifying its status as an outlier associated with its unique increase in tree canopy coverage.

Tree stress and mortality in urban areas is further intensified when impervious surface coverage is increased, as planting spaces get smaller, soil becomes more compacted, and stormwater runoff is increased.

8.5% Increase

In Overall Impervious Surface Coverage

30.5% Increase

In Overall Dwelling Units

Number of Dwelling Units

Site Nine showed a decrease in dwelling units by 3.3% (one dwelling unit), while Site Seven showed no change in density. Every other site showed an increase in dwelling unit numbers, ranging from 3% (Site Six) to 61% (Site Eight). Overall, there was a 30.6% increase in dwelling units across the project area.

Analysis

The overall change in impervious surfaces across the project area was lower than the changes in tree canopy coverage and dwelling unit counts. However, the relationship between the notable increase in dwelling units (30.6%) and almost identical decrease in tree canopy coverage (33%) is representative of the fact that as the High-Density Residential and Urban Core Residential zones densified over ten years, significant tree canopy coverage loss has generally corresponded with that development.

This relationship shows that improved planning and design are needed when developing higher-density residential buildings, with the aim of protecting existing mature trees, and also keeping newly planted trees alive past establishment and for as long as possible. The next step in the research process, Tree-Specific Site Assessment, attempts to define the main symptoms of densification, and how they might be affecting existing and newly planted street trees, and propose solutions that address these symptoms.

Precedent Study:

Oklahoma City's "Putting Down Roots"

Oklahoma City, Oklahoma adopted a detailed Comprehensive Plan developed in 2015. While Oklahoma City is much larger than Manhattan, the cities have similar climatic factors that make this precedent relevant. The city's landscape ordinance includes a detailed guidebook called "Putting Down Roots" (City of Oklahoma City) which provides information on regional conditions, site selection and design, tree species selection (with a comprehensive species list), as well as rules for planting methods and maintenance practices. These guidelines can be applied to street trees, parking lot trees, and site trees, and serve as a supplement to the Development Code for the city.

Additionally, there is a smaller document which provides a summarized planting list for Oklahoma City within the guidelines, much like the Preferred Species documents used throughout Kansas. Developed by arborists, planners, landscape architects, and educators, "Putting Down Roots" provides an exceptional guide for the implementation and care of the urban forest. The strategies outlined in this guide informed the creation of guidelines for Manhattan, Kansas in this study, while showcasing the relationship between landscape architects and other professions in the civic realm.



Figure 4.2 Oklahoma City street trees part of Project 180, supported by Silva Cells (DeepRoot 2014). One can see a beautiful, healthy tree canopy beginning to mature along this streetscape.

Design Guidelines

The content of the “Putting Down Roots” document greatly influenced the creation of design guidelines for this project. The planning committee addressed site analysis, site design, tree planting, species selection, and even proposed a year-long maintenance plan for newly planted trees. This document should be used as a precedent for Manhattan, Kansas’ planning department to aid in the planting and maintenance of the urban tree canopy, as Oklahoma City has defined goals for improving their landscaping regulations: updating landscape ordinances, educating the public on the use and maintenance of native plants, and developing better procedures for enforcing these requirements (GreenOKC). All these issues have been found to be problematic in Manhattan’s own planning process, and the planning department should consider following in Oklahoma City’s footsteps. The guidelines in this study should serve as a starting point for improving the landscape requirements in Manhattan, Kansas.

Projective Design

The guidelines developed as a result of this document directly influence the Projective Design stage of this project, as the guidelines were directly applied to designs to showcase the efficacy and applicability of them. Because the designs are compliant with the existing development code of Manhattan, Kansas, they can be considered feasible, even with alternatives applying major implementation efforts like soil cells.

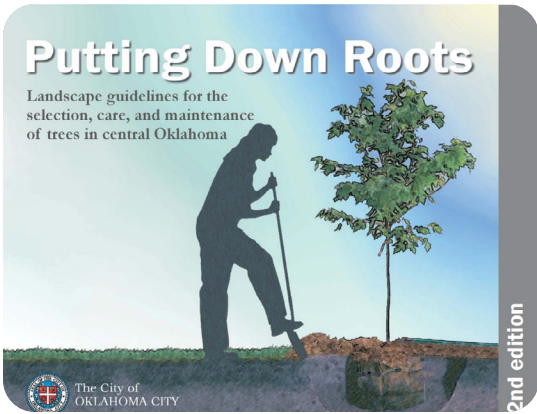


Figure 4.3 Cover of "Putting Down Roots" (City of Oklahoma City 2009).

Tree Planting Detail

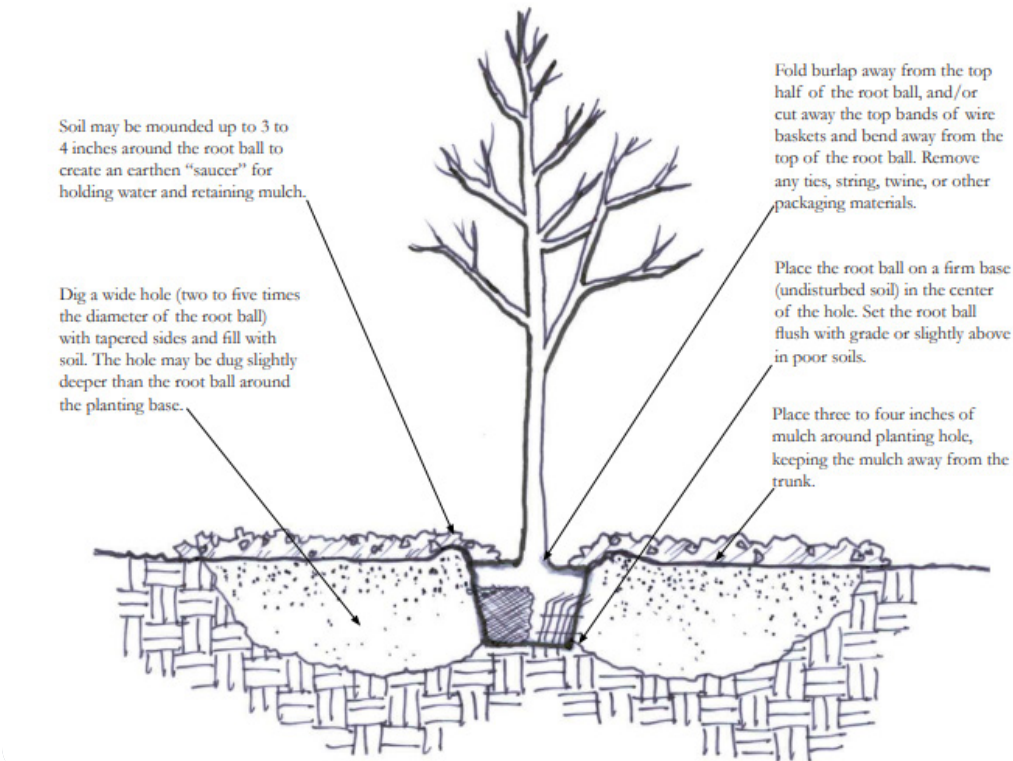


Figure 4.4 Page in "Putting Down Roots" guiding the reader on tree planting details (City of Oklahoma 2009).

Precedent Study:

Bethesda, Maryland Streetscape Standards

James Urban’s ideas on tree planting design and maintenance (shared via his book, “Up By Roots,” as well as reports and presentations) are exceptionally comprehensive, and have been applied in many different contexts in the Landscape Architecture profession. His professional website provides toolkits, articles, flashcards, as well as multiple projects on which he has worked. While his book and website were reviewed as literature, one of his past streetscape planning projects was used as a precedent.

Bethesda, Maryland has a Streetscape Standard manual (Bethesda Downtown Plan) developed by James Urban over a fifteen-year period, beginning in the 1980’s. While Urban is no longer directly involved with the planning and maintenance of Bethesda’s streetscapes and trees, the manual has been further developed since then and, as of 2020, provides standard construction detail examples for street tree planting, as development continues in the city. Like urban tree documents prepared for Oklahoma City, the manual provides guidelines for planting design and maintenance best practices.



Figure 4.5 Photo of Streetscape in Bethesda (Joe Flood 2020). One can see a beautiful, healthy, mature tree canopy along this commercial streetscape.

Design Guidelines

The Streetscape Standards for Bethesda, Maryland provide good examples of details involving soil cells, suspended pavement, and other tree planting drawings. While the outlining and content development for the guidelines proposed in this study, the drawings and diagrams for the guidelines are inspired by Bethesda. They directly apply the suggestions and process proposed by James Urban in his book “Up By Roots,” which is a goal of this project as well.

Projective Design

As principles from the guidelines are applied to the alternative proposals in the Projective Design phase of this project, the standards from Bethesda are applied at the detail scale, and will be used as a precedent for design interventions. Requirements for space, soil quality, and other design factors will be adapted from these standards as well.

While every tree in every project should have its own planting detail, these standards at least provide a benchmark for the quality of construction drawings, and a visual goal to reach.

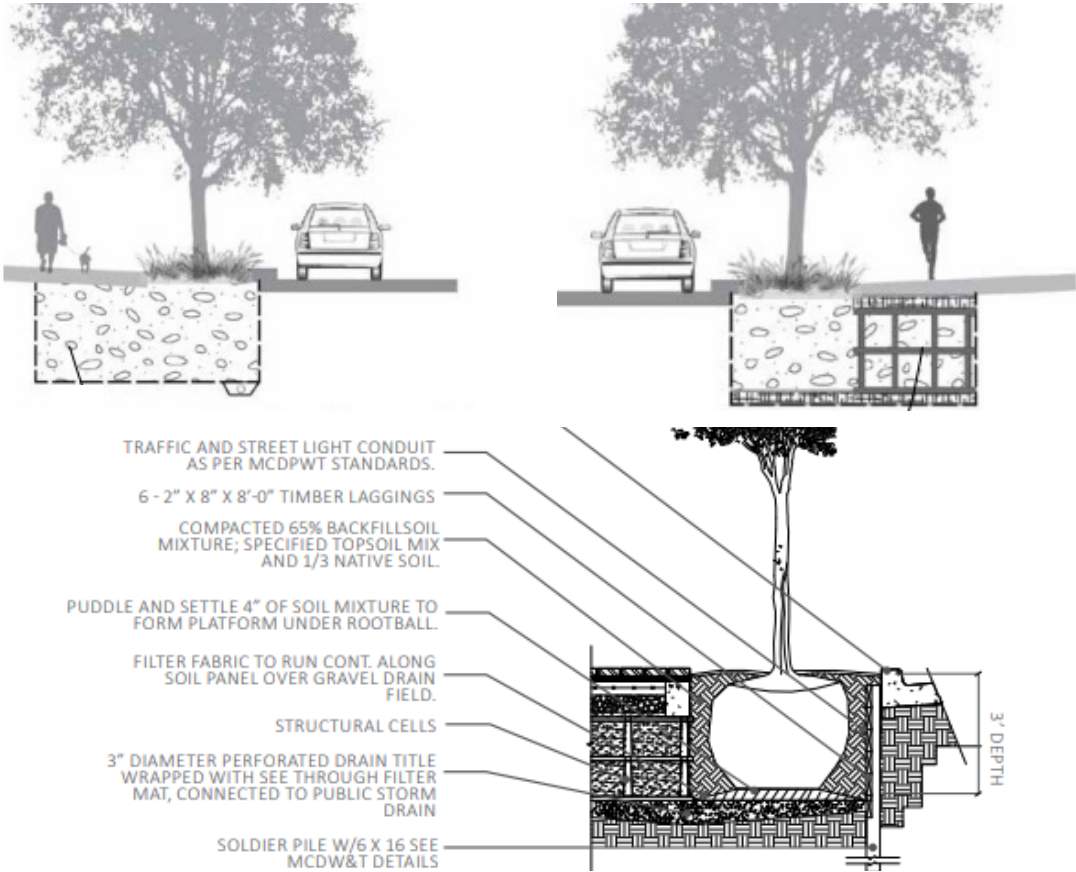


Figure 4.6 Example graphics from Bethesda, Maryland's Streetscape Standards (The Maryland-National Capital Park and Planning Commission 2020).

Precedent Study:

New York City Site Assessment Tool

In 2010, Lu et. al. conducted a study using a Site Assessment Survey for the evaluation of maintenance needs of its existing street trees in New York City (Lu et. al. 2010), and provided information on future suggested planting factors. The study defined three categories of factors related to tree health and care: biological factors (i.e., soils, water, tree appearance), urban design factors (i.e., pavement, tree grates), and sociological/stewarding factors (i.e., cues to care and maintenance). Using these categories, along with the distinction of land use types, 13,405 trees were surveyed to find the most common causes of stress and mortality.

Along with New York City Parks and Recreation, Lu et. al. also developed a document called the Site Assessment Tools Description (Watt et. al. 2010), a “step-by-step guide for city managers and researchers on how to assess early street tree survival and mortality” (Lu et. al. 2010, 12). This was developed with the intention that it would be replicated in other cities, so that other management teams can evaluate their tree canopy in the same way. Additionally, because it does not require the use of complex tools, it can be used by properly educated citizens to lighten the load on foresters and other management teams.



Figure 4.7 View of New York City Street Trees (USDA 2015). Note the diversity of sizes and types of trees along this dense urban streetscape, which provide additional shade, visual contrast to asphalt, brick, concrete, glass, and steel, help manage stormwater, and beautify the area.

Tree-Specific Site Assessment

This tool was adapted to complete an analysis of six of the ten selected sites in Manhattan, Kansas, to evaluate the existing conditions of the selected sites, and the trees that reside there. Not all the factors were relevant or feasible to measure by just one person (the study utilized 20 interns), so the most relevant and necessary factors were pulled

from each of the categories to create a table for use in the site analysis stage. The list of conditions were adapted and used to assess the conditions of 104 street trees in the project area for this study in Manhattan, Kansas.

Design Guidelines

The factors derived from the Site Assessment Tool directly influenced the creation of design guidelines. For example, “evidence of pruning” was a major factor found among the trees surveyed in the project area and was therefore addressed in the design guidelines as something to be carefully done by trained professionals or residents.

New York City’s
Young Street Tree Mortality Study



Site Assessment Tools Description



Figure 4.8 Cover page of New York City’s Young Street Tree Mortality Study (Watt et. al. 2010).

Tree-Specific Site Assessment in Manhattan, KS

Over three weeks in February of 2024, six of the 10 blocks selected in the Project Area were evaluated using the adapted Site Assessment Table. These six blocks were selected for their notable results from the overall Study Area Analysis. Sites One, Two, Three, and Five presented both dramatic Tree Canopy coverage decreases, and dwelling unit increases. Site Seven had a small increase in canopy, and no change in dwelling units, implying that the canopy increase can be attributed to tree growth. Lastly, Site Ten exhibited no change in canopy coverage, but had an increase in both dwelling units and impervious surface coverage and was therefore important to consider.

The table was printed on paper for use in the field, and the author documented photos of every tree and the surrounding context for later analysis and species identification. After the tables were completed on paper, the results and written notes were recorded in a Google Form to organize the responses and automatically display trends for better understanding and analysis. This process was intended to find similarities in the symptoms of urban conditions impacting tree health. The similarities and trends across the project area were carefully considered in creating design guidelines for improved street tree conditions.

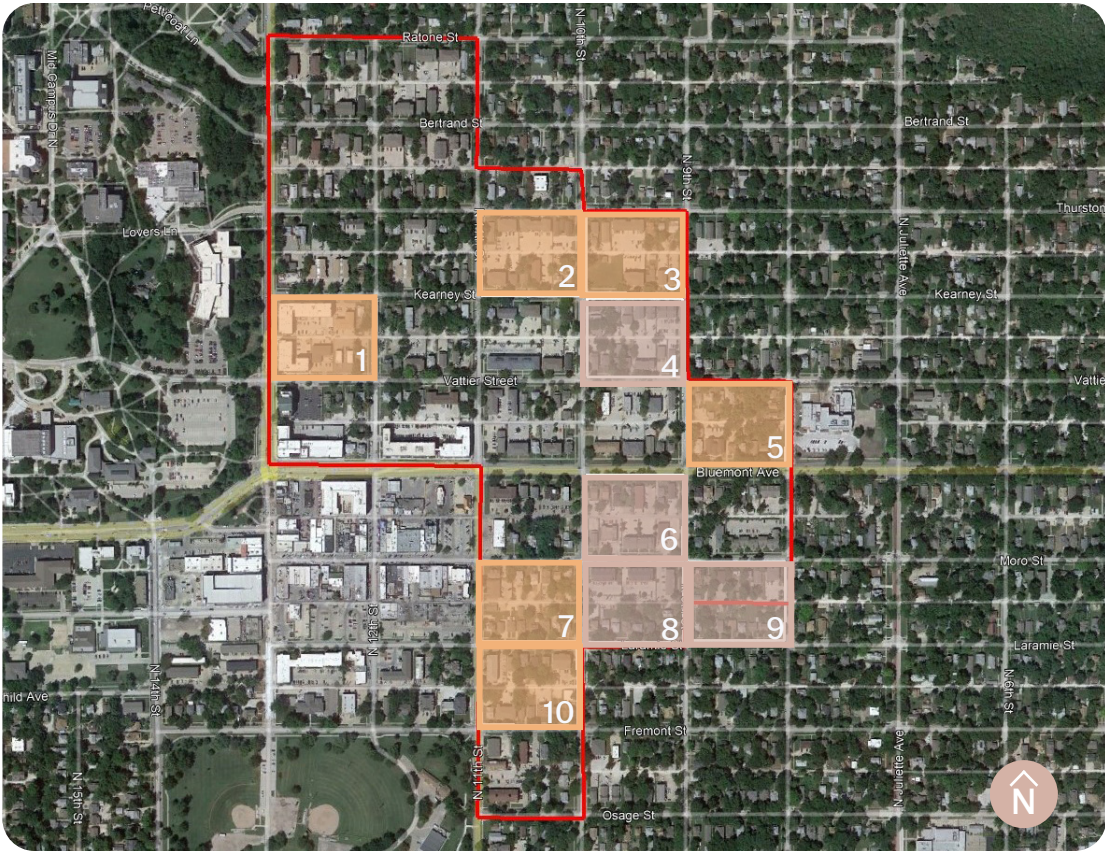


Figure 4.9 Site Assessment Selection (Saunders 2024).

Site 2: 3 (North)

Tree Health Indicators		Response (with notes as needed)
Biological Factors		
* Species of tree	botanical name	honeylocust
Height of tree 	estimated height (ft); DBH (in.)	45ft H x 35ft W
Trunk wounds or signs of suckers/shoots	yes/no - note conditions	yes - trunk is split root ball is raised above ground
Unnatural lean	yes/no - note angle of lean	no
Guard, wire, or grate girdling tree	yes/no - note conditions	no
Signs of water pooling in the tree pit	yes/no - note conditions	pooling by curb
Physical Conditions Near Each Tree		
Tree pit type	bed, lawn, median, pot, etc.	median
Tree pit size	sq. ft.	8 ft W
Tree pit distance from curb	inches	3 ft
Tree grate	yes/no	no
Curb condition	description	poor - sunken, damaged, pooling water
Sidewalk condition	description	good
Tree proximity to built structure	ft. from building facade	10 ft
Number of adjacent building stories	number of stories/floors	3
Sidewalk width near tree trunk	ft.	5.5 - 6 ft
Stakes and/or wiring present	yes/no - note conditions	no
Tree pit paved to tree trunk	yes/no - note type of paving	yes - encroaching
Mulch in tree pit	yes/no - note type and depth	no
Gravel in tree pit	yes/no - note type and depth	no
Evidence of weeds or debris in tree pit	yes/no - note type	invasive vine taking over
Evidence of pruning	yes/no - note any concerns	yes
Lights in or around tree	yes/no - note any concerns	no

bark is peeling

Figure 4.10 Example table used during site assessment (Saunders 2024).

Using the Table

During good weather over the month of February, the author visited and assessed all street trees on six of the ten sites chosen for the study. Street trees are defined as trees located within 15 feet of the front of curb, which is publicly owned and managed by the City of Manhattan, Kansas Forestry program. The trees were kept track of using pictures and a numbering system. One table was filled out for each street tree on each block, on paper to readily allow for written comments and other notes. No other measuring tools were used, and the author used the measurement of her foot (10 inches) and pace (2 feet) to estimate the width of tree canopies, sidewalk width, and other distances. Then, photos of each tree were brought back to plant ID professionals (Leslie Wren and Lee Skabelund) to correctly identify the species of the evaluated trees. Once all information was noted, the synthesized data was recorded in Google Forms.

Google Forms

A Google Form with identical questions and prompts to the physical table was used after the field analysis and follow-up plant ID with other documentation. Using Google Forms automatically created an excel sheet compiling the information, along with graphs and charts representing the responses in an organized fashion, allowing for rapid visualization and analysis of the findings.

Site Assessment Findings

Overall, 104 trees were surveyed on six sites in the project area. The results of the assessment showed important trends throughout the project area pertaining to pruning, site design, and tree planting that have informed the Manhattan-specific guidelines developed for the two selected projective design sites (blocks). The next few sections will discuss the major patterns and trends found in the tree and contextual site assessment.

Curbs and Sidewalks

Of the sites observed, 12.5% and 10.6% of curbs and sidewalks (respectively) were in poor condition. This means that they were cracked, lifted and uneven, and in some cases, posed tripping hazards. Figure 4.13 shows one of many examples of tree roots growing under the

sidewalk, lifting and destroying it over time. This conflict can result in tripping hazards, degradation of concrete and replacement costs, and damage to the tree’s roots.

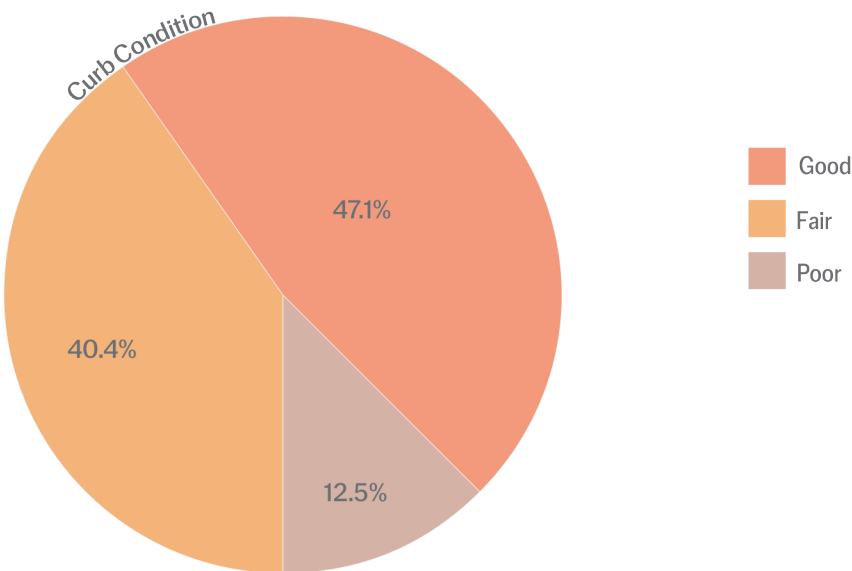


Figure 4.11 Condition of Curbs (Saunders 2024) 40.4% of curbs were in fair condition, while 12.5% were in poor condition.

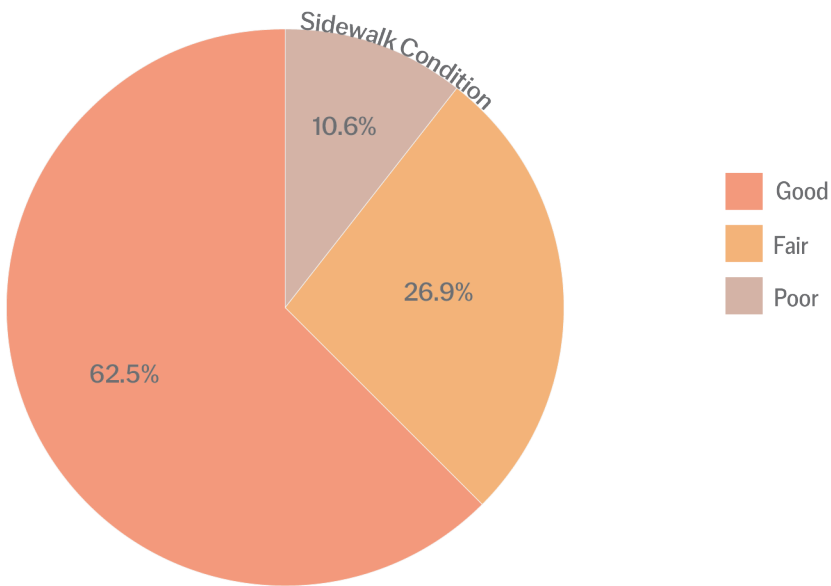


Figure 4.12 Condition of Sidewalks (Saunders 2024). 26.9% of sidewalks were in fair condition, while 10.6% were in poor condition.



Figure 4.13 Constrained tree roots causing lifted and cracked sidewalks (Saunders 2024). If tree trunks and sidewalks are too close to each other, roots can severely damage the sidewalk, presenting tripping hazards.



Figure 4.14 Constrained tree roots causing cracked and lifted curbs (Saunders 2024). Planting pits should be designed to be big enough so that tree roots do not interfere with the surrounding hardscape.

Buildings and Pruning

62.5% of trees showed evidence of very heavy, harsh, or improper pruning, including removing the main leader and/or more than a third of a tree's total mass. Through observation by the author, it could be deduced that most trees were pruned due to interference with an adjacent built structure or power lines, interference with the sidewalk, or due to branches hanging over the road.

Additionally, 61.5% of trees were only within 10-20 feet of a built structure. Some of the trees were rated “N/A” because there was not a building present. Large canopy trees should not be planted beneath power lines, but such conditions were common in the study area. Severe pruning can leave the tree vulnerable to disease and uneven weight distribution.

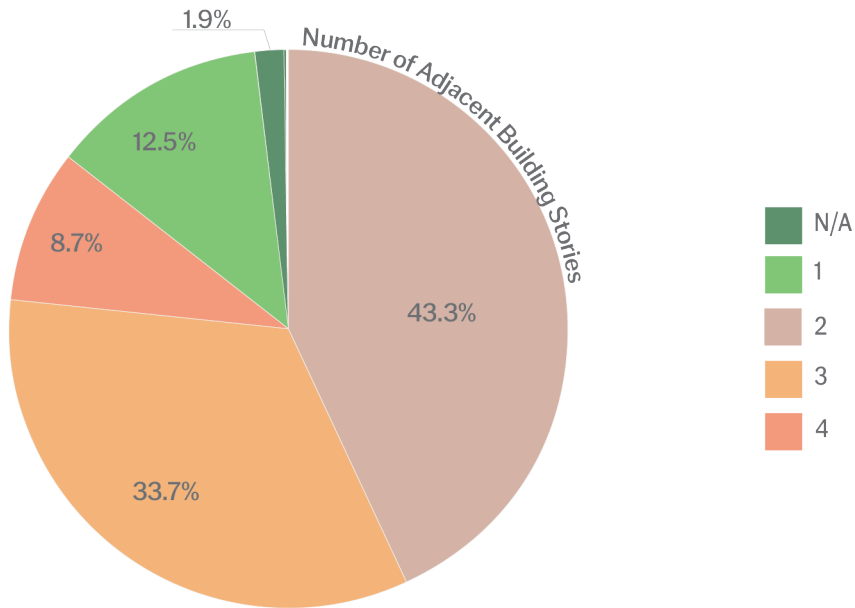


Figure 4.15 Pie chart describing number of stories close to evaluated street trees (Saunders 2024).

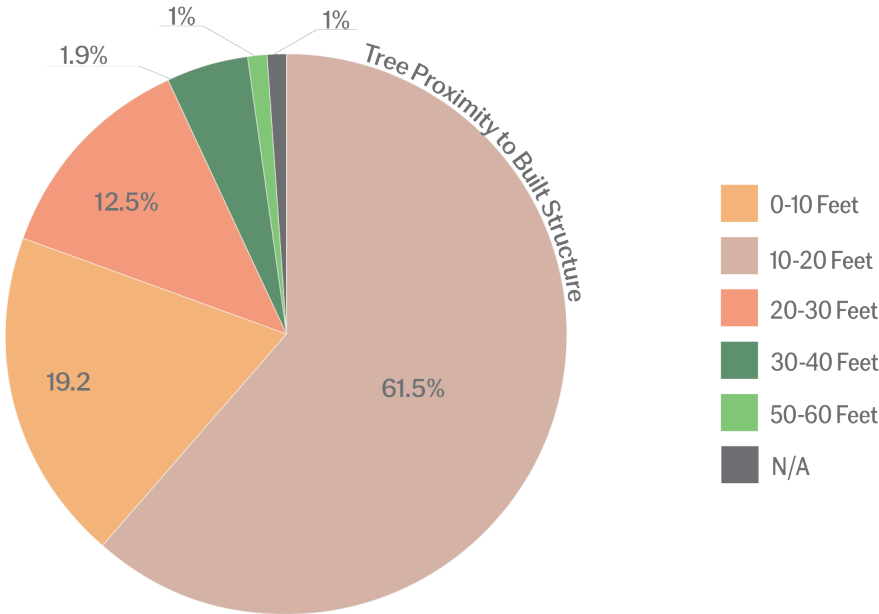


Figure 4.16 Street Trees Near Buildings (Saunders 2024). 61.5% of trees were within 10-20 feet of a built structure.

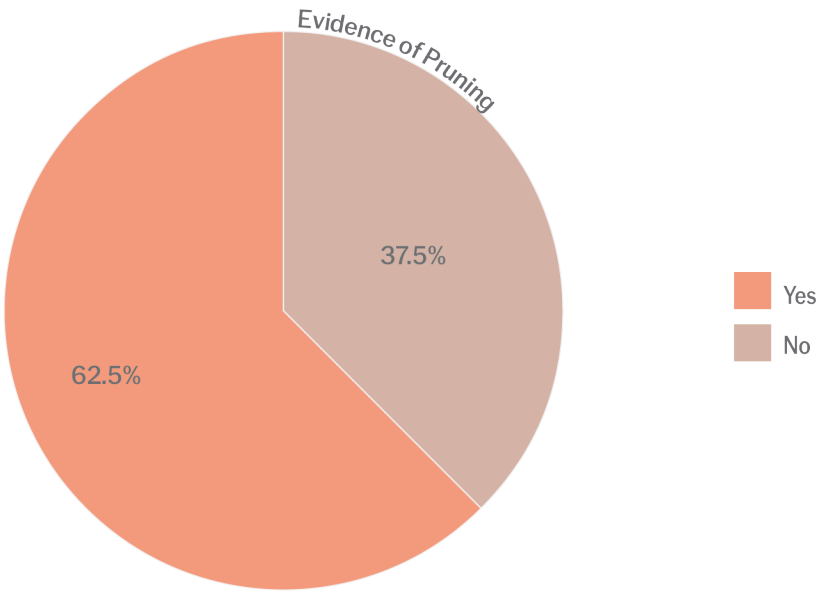


Figure 4.17 Evidence of severe pruning (Saunders 2024). 62.5% of trees were noticeably pruned.



Figure 4.18 Large Oak Tree Pruned Against Building (Saunders 2024).



Figure 4.19 Large Canopy Tree on Site Two Beneath Power Lines (Saunders 2024).

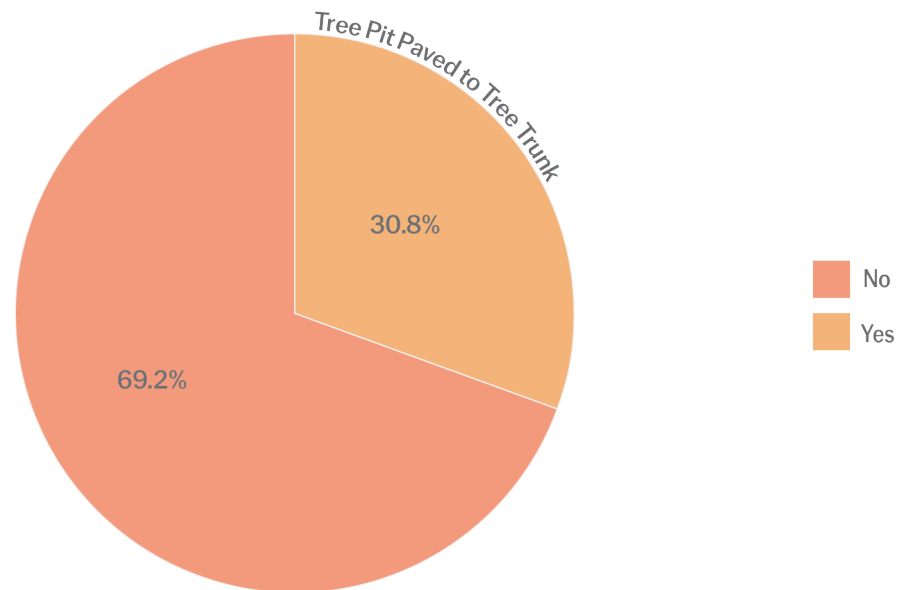


Figure 4.20 30.8% of trees had pavement right up to the trunk (Saunders 2024).

Interference with Infrastructure

30.8% of trees assessed were paved right up to their trunks. Observed was also a major interference with power lines, electrical boxes, and visible pipes and gutters. When damage is done to these urban elements, the tree is typically blamed and severely pruned or removed.

It's the responsibility of the designer or developer to ensure that every element of a site, including existing or proposed trees, have the space and volume of soil and airspace to avoid conflict between trees and infrastructure.



Figure 4.21 Large Street Tree Impacting Pipe (Saunders 2024). Utilities and trees should be considered with the same importance so they don't interfere with each other.



Figure 4.22 Ivy Climbing on Mature Street Tree (Saunders 2024). Manhattan Ivy can overtake and kill a tree if not removed.

Cues to Care

Weeds, debris, or both were observed on or around 30.7% of the observed trees. “Cues to Care” is a term used by Lu et. al. as an indicator that the tree is being maintained, and that the residents nearby care for the tree. This can include signage, weeding, and other plants in the planting bed (Lu et. al. 2010, 5).

Additionally, ivy growing up trees and taking them over was a common observation made during the site assessment. This parasitic plant can cause damage and mortality to the trees it overtakes.

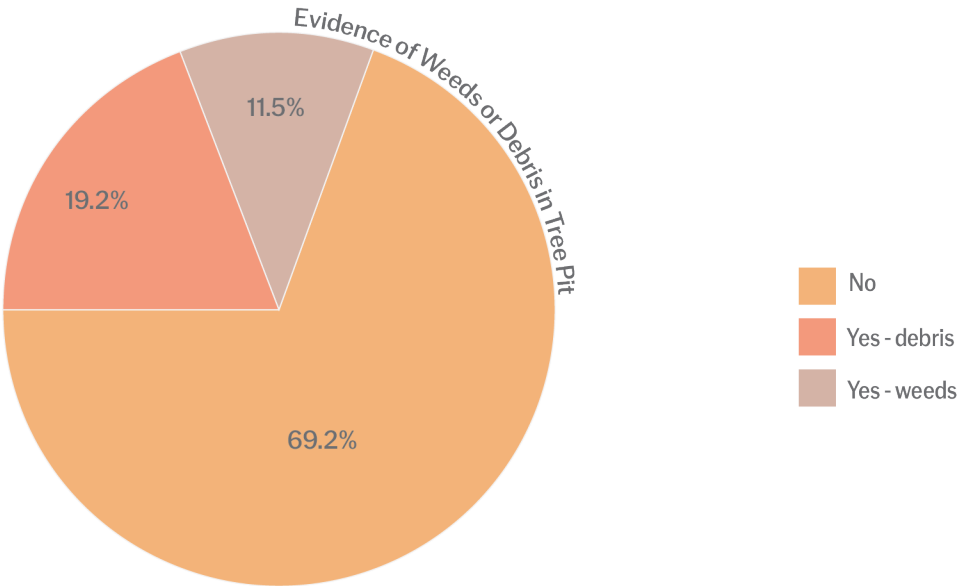


Figure 4.23 Evidence of Weeds or Debris Near Street Tree (Saunders 2024).

Design Guidelines

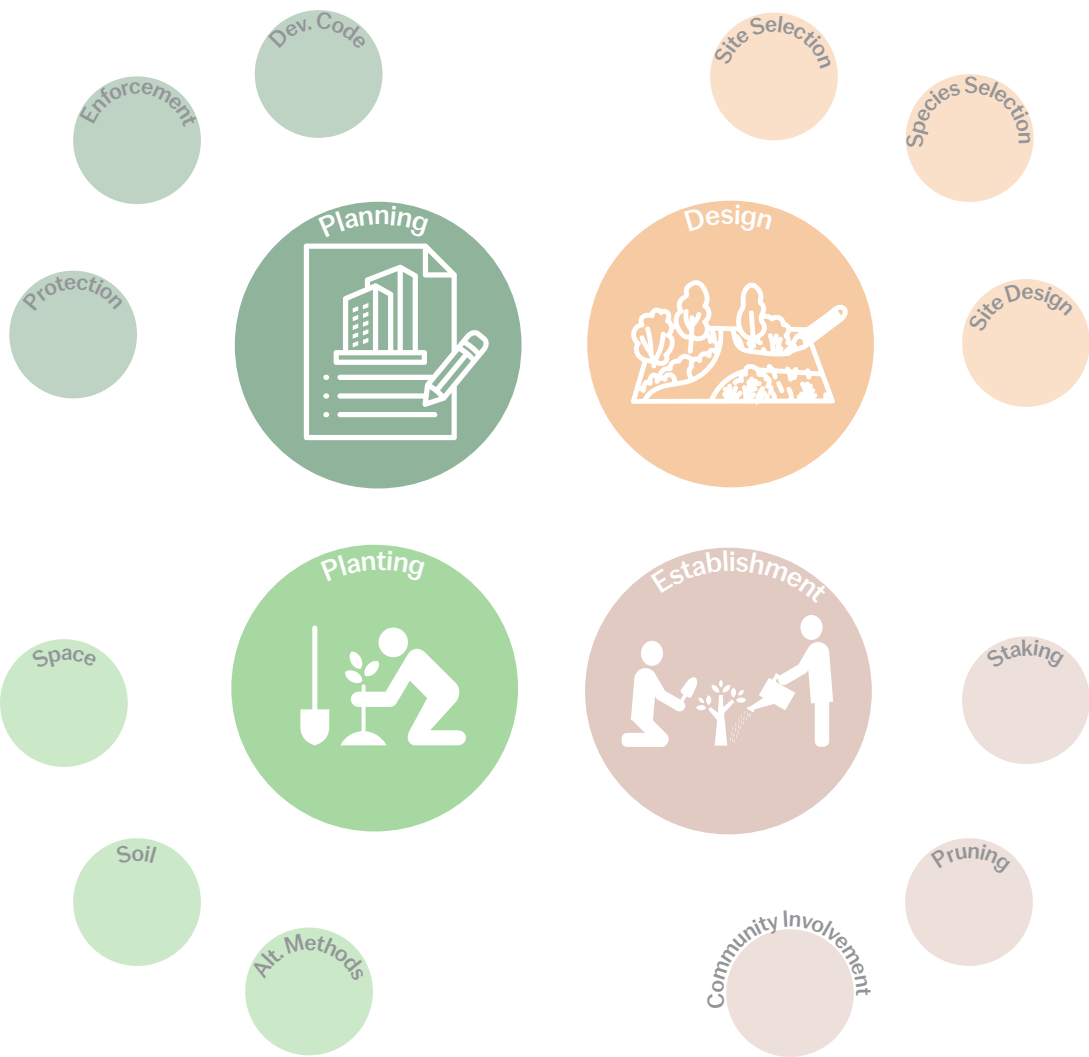


Figure 4.24 Diagram of Guideline Topics (Saunders 2024).

Introduction

The findings of the tree-specific site assessment and the project area assessment, along with knowledge gained from the literature and precedent studies, have revealed specific needs and changes to be made in relation to tree canopy coverage in the historic downtown areas of Manhattan, Kansas. For example, many trees assessed were planted too close to a structure and were severely pruned as a result. Therefore, trees must be planted farther away from built structures, sidewalks, and curbs to avoid this type of interference.

These guidelines, specific to the findings of this study conducted in Manhattan, Kansas propose implementation and design strategies with the goal of providing trees with the space, healthy soil, and establishment needs as lots in the High-Density Residential (RH) and Urban Core Residential (RC) zones continue to densify, and taller buildings continue to be built. As dwelling units in the project area increase, Manhattan planners, developers, and landscape architects should adopt a goal of increasing tree canopy coverage as well, with the standards of these guidelines in mind. As shown in Figure 4.24, the Design Guidelines that follow address planning, design, planting, and establishment needs.



Many cities around the country have increased their investment in the urban tree canopy as their benefits have become more recognized (Berland 2012, 722). However, while many cities are focused on tree planting (MillionTrees NYC, Million Trees Los Angeles, and Keep Indianapolis Beautiful, to name two recent programs), foresters must also focus on keeping those trees alive past the establishment period (Lu et. al. 2010, 2). Collaboration with soil scientists, landscape architects, and other professionals in the environmental science realm is paramount during the process of developing requirements and standards. For example, James Urban, author of “Up By Roots” stated that: “Some regulations actually require that the plan provide designated amount of canopy to shade parking surfaces, but fail to require the soil to produce that canopy” (Urban 2008, 381).

This statement highlights the need for interdisciplinary collaboration (especially between planners, designers, soil scientists, and arborists or urban foresters) during the planning process and the creation of development standards and requirements.

As Manhattan, Kansas continues to grow, more detail and consideration needs to be included in the existing Development Code (synthesized in part as Figure 4.4 to the right). Currently, the code is lenient on developers and has, in part, resulted in the continuously decreasing tree canopy. Cities like Fort Collins, Colorado and Oklahoma City, Oklahoma have great examples of comprehensive plans and development codes with goals for increasing tree canopy coverage and implementing green infrastructure.

Development Code Requirement	Min./Max.
Curb Cuts	
Located to avoid removal of existing street trees.	yes/no
Street Trees	
1 overstory tree per 40 feet of street frontage.	1 / 40 ft. min.
Removed from the R.O.W. must be replaced as close to the location as practicable.	yes/no
Green Space	
Percentage of the site to be maintained as landscaped open space.	15% min.
Min. Plant Sizes and Varieties	
Overstory Trees	2.5 in. caliper
Understory Trees	1.5 in. caliper
Evergreen/Conifers	6 ft. tall
Shrubs	2 gal. container
Ornamental Grasses	1 gal. container
Min. Landscape Planting Requirements	
Building Foundations	
Next to and along no less than 30 percent of all building foundation lines that face or front a public street or private drive and not in a clearvision triangle area.	30% min.
Street Trees	
Within the tree lawn of a street right-of-way and not in a clear vision triangle area.	yes/no
One overstory tree (minimum 10' tall) for every 50' of street frontage, excluding driveways.	1/50'
Off-Street Parking Areas	
All rows of parking must be terminated with a curbed landscaped island.	9'x16' min.
Max. distance a tree can be from a parking space.	70' max.
Landscaping must be along at least 75% of the linear feet of frontage between the parking lot and the adjoining public street or private drive.	75% min.
All parking lot landscape islands must be landscaped with a combination of turf grass, prairie grass, plant beds, rock, wood chips, or shrubs, and trees.	yes/no
One overstory tree must be planted within each required landscape island.	1 overstory tree min.
Tree Preservation Credit	
6-12 in. caliper	3 overstory trees
12-24 in. caliper	4 overstory trees
24-36 in. caliper	5 overstory trees
>36 in. caliper	6 overstory trees

Table 4.3 Select Development Code requirements (Saunders 2024). Full table used during design process is located in Appendix 3.

Manhattan Development Code

Minimum Landscape Requirements

Currently, Manhattan’s Comprehensive Plan does not mention the growth of its urban tree canopy, nor does it address the decrease in tree canopy coverage (Manhattan Urban Area Comprehensive Plan). Considering its status as a “Tree City USA,” commissioners, planners, and foresters should be prioritizing tree planting, growth, and conservation as densification occurs. During the Projective Design process for this study, the Development Code was used to confirm the feasibility of the proposal and to determine potential shortcomings that could be improved upon. Compared to the detail of tree planting and conservation content found in other comprehensive plans, Manhattan has much room for improvement.

Currently, the Development Code requires one overstory tree to be planted in every landscaped island (Manhattan, KS Table 26-7C-3.1). An overstory tree is defined as a tree reaching at least 30 feet in width at maturity. However, the minimum size for a landscaped island is 9 feet by 16 feet, or 144 square feet (Manhattan, KS Table 26-7C-3.1). This amount of soil, surrounded by the impervious surface of a parking lot, is not adequate to support a tree of this size. According to James Urban, the area of the tree canopy multiplied by 3 feet of depth, is approximately the amount of soil needed to support a tree (Urban 2008, 94). Either the tree will never reach maturity (defeating the purpose of requiring an “overstory” tree), it will die before it is fully established, or it will cause considerable damage to the pavement around it (increasing the possibility of the tree being removed). Therefore, it is suggested that understory trees be required in parking islands or, preferably, the minimum size requirement for a landscaped island is increased based on the canopy size expected for the tree species planted or to be conserved.

Figure 4.25 Illustrated Landscaping Requirements of Manhattan Development Code (MHK-DC). Refer to Manhattan, KS Development Code, Figure 26-7C-3.1 for more information.

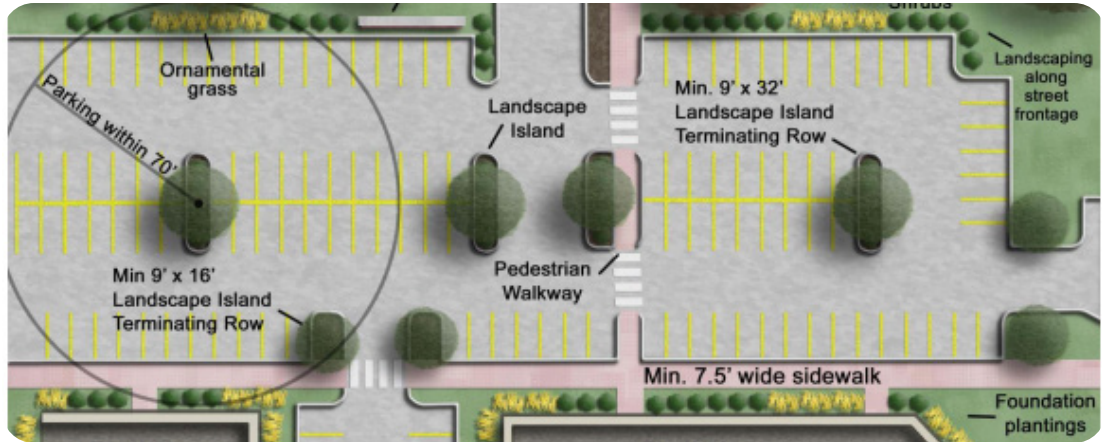


Figure 4.26 Small island within parking lot in the Project Area (Saunders 2024). Island sizes (and possibly soil type/quality) are general inadequate to support healthy tree growth in areas surrounded by cars and impermeable paving.

Manhattan Development Code

Tree Preservation Credit

While tree preservation should absolutely be encouraged and practiced, Manhattan’s Development Code allows preservation to replace tree planting. So, if a street frontage of 100 feet has two existing mature trees with a 6–12-inch caliper, developers do not have to plant any trees at all in that area. After reviewing the literature and developing these guidelines, it is determined that not only should it be required that trees be preserved, but that newly planted trees should still be required to increase the tree canopy in Manhattan. Additionally, it is clear that Manhattan simply has a “try your best” attitude about preserving existing trees. For example, curb cuts must be located to avoid the removal of existing trees, but they can just be replaced with a new tree if the existing one is removed (Manhattan, KS Article 26-4-C.1).

Since there are no real consequences for removing existing trees, developers can get away with their current practices. Importantly, this does not account for tree removal after construction. During site assessment, it was observed that new buildings were built too close to existing mature trees, and then when that tree inevitably interfered with the structure, it was removed or severely pruned. Requiring developers to build and develop around existing trees will assist in preserving the existing tree canopy while also working to increase it by planting new, young trees.



Urban vs. Natural Sites

When planting trees in a natural, park-like setting, the soil conditions, vehicular and pedestrian traffic, and space provided for each tree are all drastically different from a dense urban setting. Building density, repetitive construction, and the increase of impervious surfaces lead to restricted soil space, and harsh growing conditions for trees contributing to the urban canopy (Berland 2012, 735; Watson et. al. 2014, 249; Steenberg et. al. 2017, 119). While trees can contribute numerous benefits to the urban fabric, discussed in Chapter 2, they need to be designed for, planted, and maintained differently than one in a naturalized

setting. It also needs to be considered that the canopy will not be as large or full as a designer would like in an urban setting since root and canopy space are restricted, and excessive pruning becomes an issue as trees mature and grow to conflict with infrastructure (Steenberg et. Al. 2017, 119). A study done by Nowak in 1990 revealed that even the land use of a site affected tree mortality, with apartments showing increased mortality, and single-family homes showing decreased mortality (Nowak et. al. 1990, 129).

According to James Urban in his 2008 book “Up By Roots,” all urban soil is compacted and low in nutrients, making it difficult for trees to thrive in. Due to large areas of pavement, the soil is cut off from nutrient cycling and from a lack of organic matter entering it. Additionally, digging and grading during construction, removing and replacing the soil, causes compaction, where the structure of the soil is disrupted, and less air is available to tree roots. Compaction, along with an elevated pH from construction materials like concrete and brick, elevated salt levels from de-icing solutions, and a raised temperature from the

Urban Heat Island effect of all cities, lead to poor growing conditions, and often result in urban tree mortality (Urban 2008, 108-114).

Due to the difficult growing conditions, it is the responsibility of the designer to consider these challenges as housing density in urban areas increases, and buildings get bigger, while planting areas get smaller. Choosing the right tree, for the right place, with the right support, will allow trees to grow to their full potential and contribute to a healthy urban canopy.

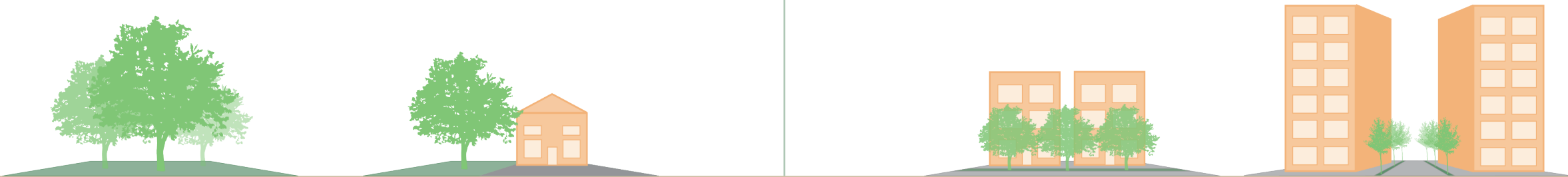


Figure 4.27 Diagram of trees planted in different contexts (Saunders 2024). From left: naturalized, single-family residential, townhomes, and multi-family development.

Species Selection

Choosing the right tree is one of the most important considerations to make when designing. Depending on the needs of a site (soil compaction, space, aesthetic and environmental goals), choosing the right trees can determine the success of every design. Additionally, every tree is different, with different water needs, root growth patterns, growth habits, and hardiness. For example, fast-growing trees, which may be desirable for a client to see results as soon as possible, have weak wood and tend to require more management, along with having a short lifespan (Petri et. al. 2016, 109).

Strong, drought-tolerant trees should primarily be used in urban areas, as they are hardy enough to survive harsh conditions, and can bring benefits to sites that need it most. It's important to note that not all these trees are suitable for urban areas, and some species are even considered invasive. This highlights the need for consultation of horticulturists and soil scientists, as well as mindful consideration for the species selected for

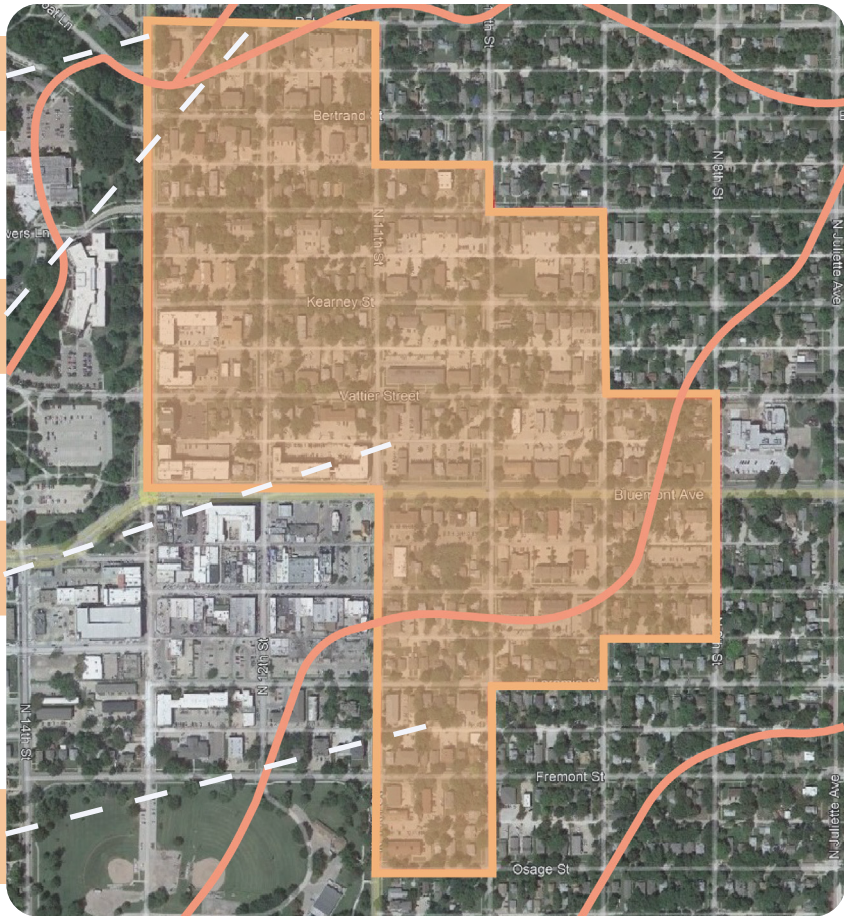
each individual site. The Kansas Forest Service also provides an interactive Kansas soils map called “The Right Tree for My Soil” (The Right Tree for my Soil 2023) which provides the best tree species to plant based on the soil profile for any site in Kansas. Of course, tree selection must also be made with the intentions of the design in mind. One would not plant a large tree (expecting it to grow to full maturity) in a parking island. In that case, a smaller, hardy, drought-tolerant native or non-invasive ornamental tree is likely more appropriate. Additionally, there is a limitation to using this tool, which only considers the natural state of the soil, and not the urbanized conditions. Therefore, it is important to have a site-specific soil test done to determine the qualities and characteristics of the soils trees are to be planted in for each individual site that is developed.

Smolan silt loam

Reading silt loam

Chase silty clay loam

Reading silt loam



Species Selection

Certain tree species react uniquely to urban conditions like soil compaction, poor drainage, and disease (Coder 2000, 2; Craul 1999, 219; Steenberg et. al. 2017, 120). While the commonly used “Preferred Trees for Northeast Kansas” list, provided by the Kansas Forest Service (2018), is a good representation of native species to plant, not all of them should be used in harsh conditions. A list of suitable trees and shrubs that grow on difficult sites is also provided by the Kansas Forest Service (Table 4.6), and notes the alkaline tolerance, wildlife value, flooding tolerance, and other remarks (refer to "Trees and Shrubs for Difficult Sites," Robinson 2006).

Additionally, biodiversity is very important when considering species selection (Nitoslawski et. al. 2017). In his book “Up By Roots,” James Urban commonly employs the 10/20/30 rule of tree biodiversity: no more than 10% of trees from one species, no more than 20% from one genus, and no more than 30% from one family. This strategy can prevent diseases like the emerald ash borer from wiping out entire or large populations of urban trees, and helps vary the aesthetic conditions of a design (Urban 2008, 340).

Name (Common)	Name (Scientific)	Height	Wildlife Value
Goldenrain tree (invasive)	Koeleruteria paniculata	30'-50'	Fair
Hackberry	Celtis occidentalis	50'-100'	Good
Hawthorn, Cockspur	Crataegus crusgalli	20'-35'	Good
Hickory, Shagbark	Carya ovata	75'-100'	Excellent
Honeylocust	Gleditsia triacanthos	50'-75'	Fair
Oak, Black Jack	Quercus marilandica	35'-50'	Excellent
Oak, Bur	Quercus macrocarpa	50'-75'	Excellent
Oak, Ckinkapin	Quercus muehlenbergii	35'-50'	Excellent
Osage Orange	Maclura pomifera	35'-50'	Good
Ash, Green	Fraxinus pennsylvanica	50'-75'	Fair
Cottonwood	Populus deltoides	75'-100'	Fair
Hackberry	Celtis occidentalis	50'-100'	Good
Hickory, Shellbark	Carya laciniosa	75'-100'	Excellent
Linden, American (Basswood)	Tilia americana	75'-100'	Fair
Mulberry, Red	Morus rubra	35'-50'	Excellent
Oak, Pin	Quercus palustris	75'-100'	Excellent
Oak, Red	Quercus rubra	75'-100'	Excellent
Oak, Swamp White	Quercus bicolor	40'-60'	Excellent
Pecan	Carya illinoensis	75'-100'	Excellent
American Sycamore	Platinus occidentalis	75'-100'	Fair
Willow, Black	Salix nigra	35'-50'	Fair
Willow, Peach-leaved	Salix amygdaloides	35'-50'	Fair

Table 4.4 Adapted list of Trees and Shrubs for Difficult Sites (Saunders 2024). For full table with remarks see the Kansas Forest Service publication "Trees and Shrubs for Difficult Sites" (Robinson 2006).

Site Design

Interference with infrastructure, buildings, and pavement can cause stress and mortality in trees, while also causing damage to the infrastructure in question. Designing a site with the intention of providing ample space (both above and below ground), quality soil, and the proper protection strategies can mitigate these conflicts overhead, at the eye level, and below ground.

James Urban, author of “Up By Roots,” suggests “planting the easy places first.” Simply, the areas that have the most appropriate amount of soil volume should be planted first, and the places outside of that may not be suitable for large trees. Trees can share soil volume, so one large planting space can support more trees than several small beds (Urban 2008, 377).

Figure 4.29 Tree interfering with adjacent balcony (Saunders 2024).

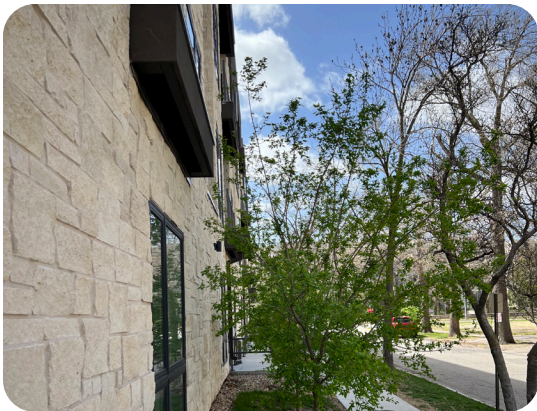


Figure 4.30 Severely pruned tree due to interference with powerlines (Saunders 2024).

Overhead Conflicts

Many new buildings implemented near mature trees are placed too close, resulting in tree branches growing over roofs, against windows, and into balconies. Obviously, this is undesirable, and is often the defense behind severe pruning of trees, or even the removal of trees (Watson et. al. 2014, 249). To prevent this measure, consider the existing tree as equally important as the sidewalk, curb, or building entrance. Designing a building to complement the tree will not only make for a more interesting design but will protect both the tree and building from future interference with each other. When proposing new trees to a design, ensure that their estimated mature size is represented on landscape plans, to ensure that they will not pose any problems to the surrounding infrastructure in the future (Urban 2008, 398).

Do not plant trees under or near power lines. This was a common issue found during site assessment, as many trees were severely pruned into an interesting looking “V” shape, around power lines they were growing into.

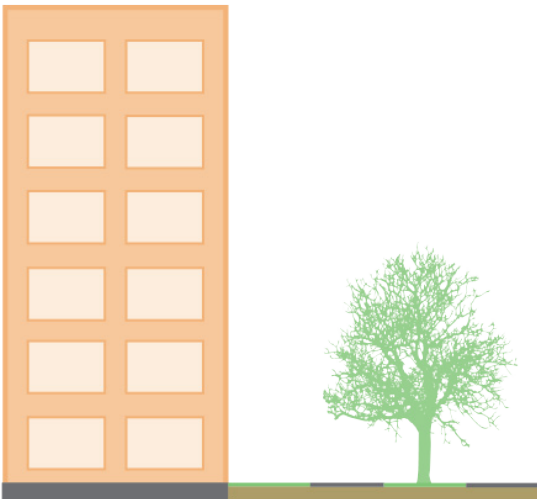
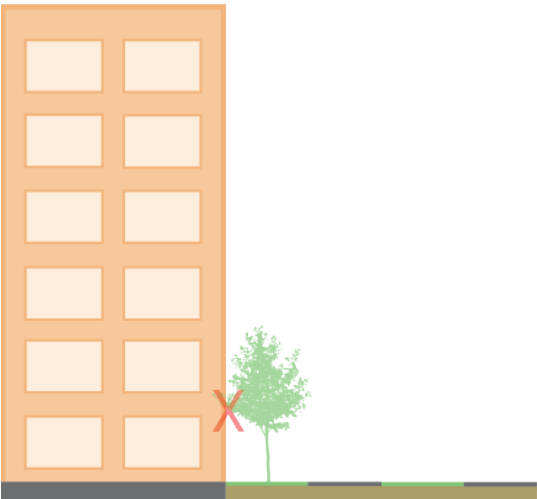


Figure 4.31 Proximity of trees to nearby buildings (Saunders 2024). Making larger planting spaces and giving trees the space they need at their mature size will prevent future conflicts.

Eye-Level Conflicts

In areas with lots of pedestrian traffic, as is the case in the study area, given its proximity to Kansas State University, pedestrians, animals, and vehicular traffic can raise issues with the tree trunk. Cars accidentally drive up onto a curb, or people consistently walk over the roots, and trees are vandalized. While seemingly minor, these issues can cause stress to a tree. To prevent consistent pedestrian interference or animal waste, consider using a perimeter tree pit guard (Figure 4.33) around the trunk and all or part of the planting bed. Tree pit guards can also reduce vehicular damage and is a “cue to care” showing that someone is maintaining the tree (Lu et. al. 2010, 10). Tree grates should never be used, and barriers should be at least 18-24 inches in height to not become a tripping hazard (Urban 2008, 268).



Figure 4.32 Litter left in a damaged tree (Saunders 2024).



Figure 4.33 Tree fence around the planting bed (Wil540 2022). Tree fences help prevent pedestrians from disturbing tree roots and the understory.

Figure 4.34 Damaged sidewalk (Saunders 2024).

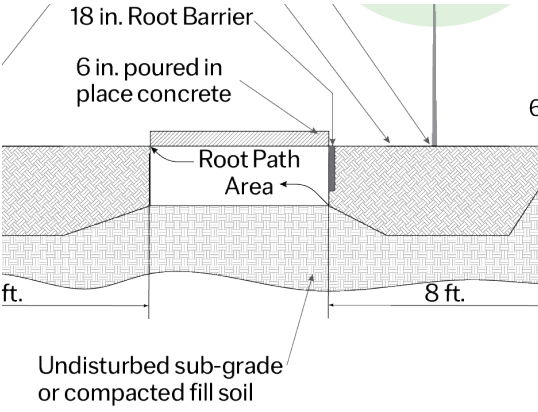
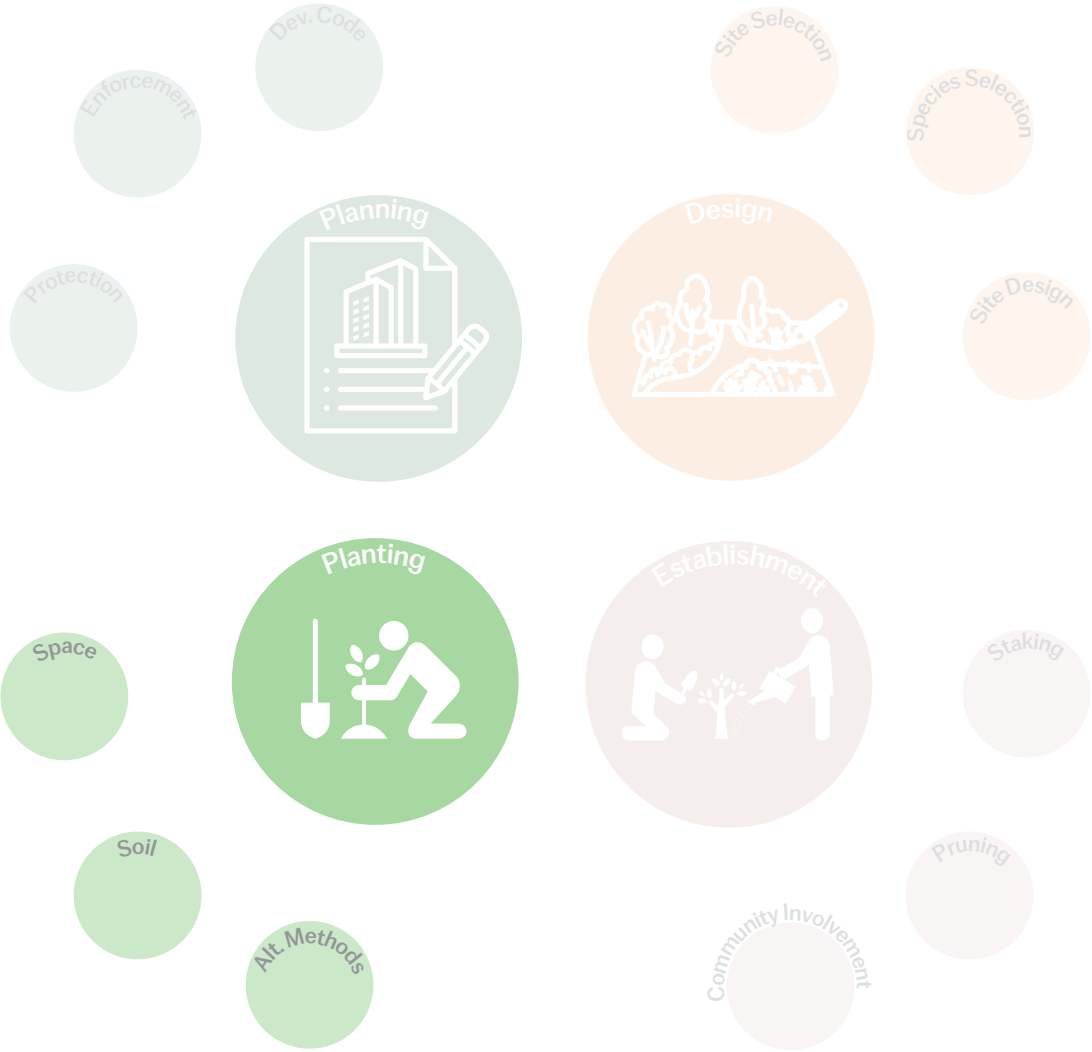


Figure 4.35 Root Growth Detail (Saunders 2024). Root barriers and root paths can redirect roots into more appropriate soil space, and prevent cracked and lifted sidewalks.

Below-Ground Conflicts

Proper site analysis is needed to ensure that tree roots will not interfere with underground utilities. This sort of interference can cause major issues to residents, the tree, and the city. Additionally, trees should be provided with the largest planting space possible, and paving and planting space should be considered equally in the design process. One of the most common issues found in the Site Assessment was conflict with adjacent paving and sidewalks. Again, providing adequate soil space and planting trees near or away from sidewalks and other adjacent utilities will aid in this dilemma and prevent the destruction of sidewalks.



Space

According to Craul, a soil scientist focused on providing landscape architects with the proper information to plant and maintain trees that will thrive in urban environments, there are five criteria of tree planting: 1) a sufficient amount of good soil, 2) sufficient moisture, 3) proper drainage, 4) proper aeration of the soil, and 5) a supply of plant food (Craul 1999, 214).

Sufficient space and soil depth are the most crucial and perhaps hardest to come by factors in tree planting. According to James Urban at the 2007 ASLA conference, a large tree (50 or more feet in canopy diameter) will need 1000 cubic feet or more of soil (Urban 2007). However, in urban environments where most of a design is dedicated to sidewalks, building footprints, and

parking, trees are not being provided with that volume. This will lead to trees that will require more maintenance, will not grow to full maturity, and will have a shorter lifespan (Watson et. al. 2014, 259). Therefore, space must be provided to the fullest extent possible, and measures must be taken to alleviate the stress of small spaces. As shown in Figure 4.36 a parking area on the north side of the Municipal Center in Ann Arbor, Michigan has over 12,300 square feet of concrete permeable paving units. A granular sub-base beneath the pavers provides temporary storage for stormwater detention and infiltration while providing additional moisture to the trees planted in 2012 (LAF 2013).

"The key to the choice of the most successful planting techniques is to match the proper technique to the condition presented by the urban situation."

(Craul 1999,214-215).



Figure 4.36 Parking Lot Trees at the Ann Arbor Municipal Center (Skabelund 2022). Trees in this Ann Arbor, Michigan parking lot have been given soil space surrounded by permeable pavement to allow for adequate root spreading and access to extra water.

Space

Typical Space Needs

A common misconception about the root system of a tree is that it grows deep, rather than far. In fact, it looks more like a plate, and the canopy diameter of a tree will typically mirror the root plate diameter. According to Phillip Craul, “The dug pit should be slightly less than the depth of the root system. The width should at least be twice the diameter of the root system” (Craul 1999, 220).

In the design stages for a development, planting pits must be as large as possible, especially when they are surrounded by pavement, common for an urban context. Consider tree planting space and paving space with equal importance, designing paving with “the minimum width needed for the use of the space, and the area for tree planting designed to be the largest size practical”

"- a large tree needs more than 1,000 cubic feet of soil to reach the size where it becomes a significant contributor to a healthy urban ecosystem."

(Urban 2007, 1).

(Urban 2008, 157). Additionally, not only does the root system need adequate space, but the root flare at the base of the tree does as well. Tree grates, tree guards, and lights can hinder the growth of the tree, to the point of girdling it to death. Even planted understory trees and shrubs should be an adequate distance away from the trunk, and only mulch should be present right at the base of a newly planted tree (Urban 2008, 160).

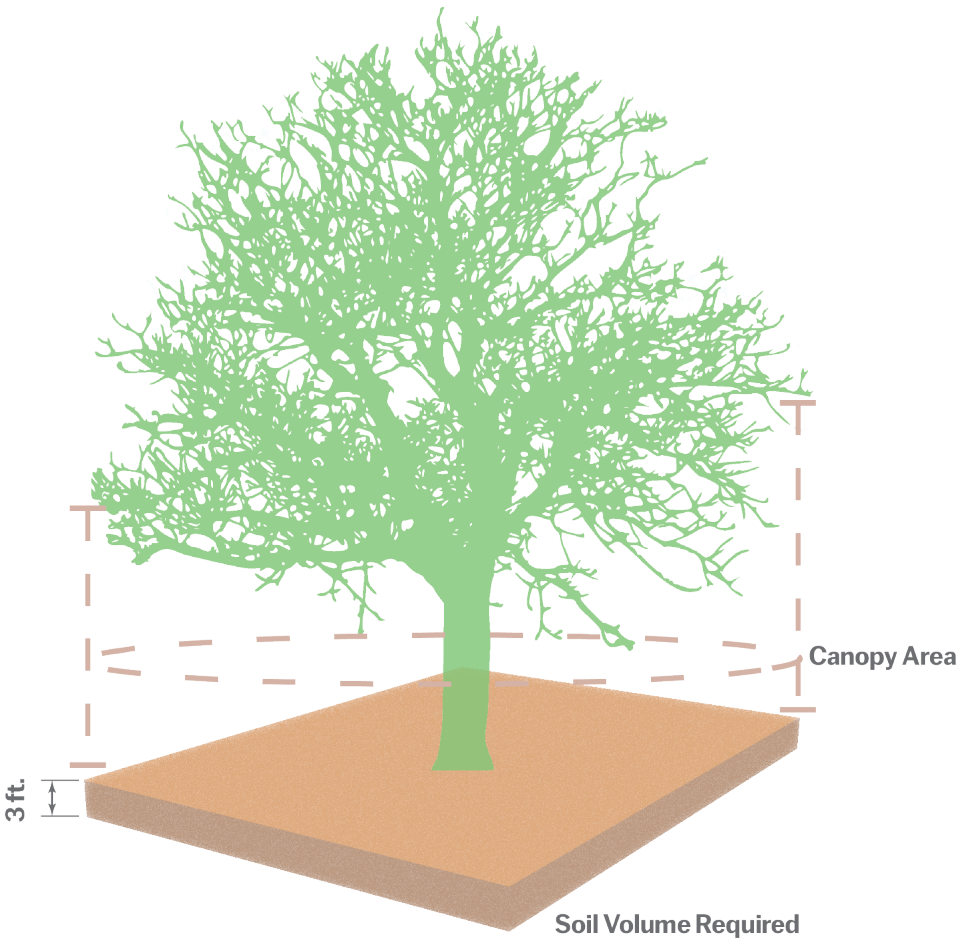


Figure 4.37 Diagram of space needed by a tree based on how large it is at maturity (Saunders 2024).

Soil Compaction and Disturbance

Once soil has been disturbed – by moving, digging, or paving over – the structure of the soil is lost, reducing its ability to support plant life (Urban 2008, 163). As soil is disturbed again through development and redevelopment, it becomes more and more compacted, losing nutrients, aeration, drainage capabilities. This reduces a tree’s ability to grow, as root space is restricted and water filtration is reduced (Steenberg et. al. 2017, 120). Since Manhattan’s Urban Core and High-Density Residential zones are mostly developed and paved over, most of the soil can be considered compacted, urban soils.

What If My Site Doesn't Have Enough Space?

When a tree is placed in a pit or bed with little space for robust root growth, the tree is at risk for many things, Soil compaction, damage from vehicular and pedestrian traffic, and conflict with surrounding pavement and infrastructure are all potential problems faced by trees in small spaces. Therefore, alternate paving options (such as bricks or other types of loose set pavers) can reduce the impact tree roots having on its surroundings. However, the maintenance required for this option could be expensive, as bricks may need to be replaced as they are lifted and shifted when the tree grows. Additionally, curbs, low fences, and barriers around the planting pit or bed (NOT right next to the tree trunk!) can prevent damage from pedestrians and vehicles. A minimum curb or fence height of 18-24 inches is suggested (Urban 2008, 268-284).

When space is insufficient, soil quality becomes important, and can potentially alleviate the effects of limited space, when combined with maintenance (Watson et. al. 2014, 259). However, when space simply cannot be found, it may be better to plant fewer or smaller trees, and to provide adequate resources for the trees that can be planted. Construction drawings and sections should always represent a proposed tree at its largest size expected, which will be different for every tree, and depends on the soil and space conditions. The alternative methods for tree planting discussed in the next section of this may alleviate some of the issues related to soil compaction, aeration problems, and root girdling upon planting.

Planting Methods

Bare-Root Planting

Bare-root trees are less expensive, more easily transported, and their roots can be pruned of issues before planted in their respective pits (Jack-Scott 2011, 1). Additionally, they remove less topsoil at the nursery, and more of the roots are put in direct contact with soil (Urban 2011, 54). Bare-root planting is a feasible option to be explored when considering tree planting in the design process. However, there is more sensitivity to the time of planting, and the individual species (Urban 2011, 55). Additionally, bare-root trees are usually planted at a small size and take several years or more to reach their intended size. Therefore, the impact to the design upon planting must be considered.

Figure 4.38 Bare-root planting a small tree (Smith 2022).



Figure 4.39 Balled-and-burlapped planting is a common practice in landscape design (JoLynne Martinez 2019).

Container Planting

As the most common tree planting method in this region, the problems known to this method include circling and kinking roots from leaving trees in the container for too long (Urban 2008, 404). Beware of trees that have been continuously repotted, as the outer roots will have been trimmed back, but interior roots could continue to circle and kill the tree. Additionally, over-trimming the roots can prevent water intake and eventually kill the tree after it is planted. Understanding the problems and benefits unique to each planting method is important, and one may be better than the other depending on the nursery, caliper size, and species of the tree.

Balled-and-Burlapped

Balled-and-Burlapped trees are favorable as they recover quickly upon planting and have few root problems if dug correctly (Urban 2008, 400). Large balls of dirt are wrapped around the root package with a burlap sack for transport, and this package is placed directly into the area it is intended for. However, the energy required to ship and move large amounts of soil is costly (economically and environmentally) and the burlap must be biodegradable. Additionally, these trees can always be subject to the same problems as container or bare-root trees if planted too deeply, the wires aren't cut correctly, or roots are pruned incorrectly (Urban 2008, 402).

Mulching

Organic mulch is the best management practice for trees in their establishment phase (Urban 2008, 275). The layer should be 2-3 inches thick and should be replaced every several years. It should not be allowed to build up immediately around the trunk, as it can cause bark rot, girdling roots, and damage from small rodents (Urban 2008, 275). Mulch provides protection to the soil surface from compaction and crusting, traps soil moisture, reduces soil temperature during hot summer days, prevents competitive weed growth, and adds organic matter and nutrients to the soil (Craul 1999, 224).



Figure 4.41 "Mulch Volcanoes" choking the base of a tree (Cue).

Pervious Paving

As stated before, modular, pervious paving such as brick can be molded as the adjacent tree grows, and can decrease conflicts. As a tree comes into contact with impervious concrete, it adds wood (root mass) to the affected area, and can disrupt or destroy the infrastructure around it. Loose-set pavers can prevent this kind of damage. Additionally, pervious pavers allow more water, air, and nutrients to the soil below it, which can make up for a lack of soil volume (Urban 2008, 269).



Figure 4.40 Pervious paving in a parking lot (NACTO).

Soil Amendments

In urban environments, the lack of aeration and drainage, as well as the presence of impervious surfaces, can restrict the nutritional value of soils. When planting a tree in these conditions, it may be necessary to introduce organic soil amendments to the planting soil around the root ball. These amendments can include mycorrhizal fungi, lime, sulfur, leaf matter, peat moss, and compost. The amendments would vary based on the condition of the soil, and the tree species needs, so consultation with a horticultural or soil professional is important (Urban 2008, 176).

Root Barriers and Paths

James Urban describes root paths as a “low-cost way to guide roots out of confined planting spaces” (Urban 2008, 296). Trenches are dug under pavement where more soil volume can be provided for roots to grow under, and prevents pavement from being damaged by tree roots trying to force their way out of a small space. Coupled with root barriers guiding roots far under pavement, roots can be provided with proper aeration and volume, especially when there is additional volume on the other side of a sidewalk, for example.

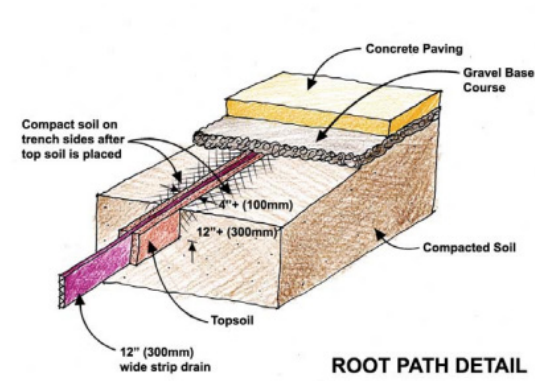


Figure 4.42 Root path detail (Urban).

Soil Cells

Figure 4.43 Newly installed honeylocust trees in Silva Cells at Union Plaza in Lincoln, Nebraska (Skabelund 2017).

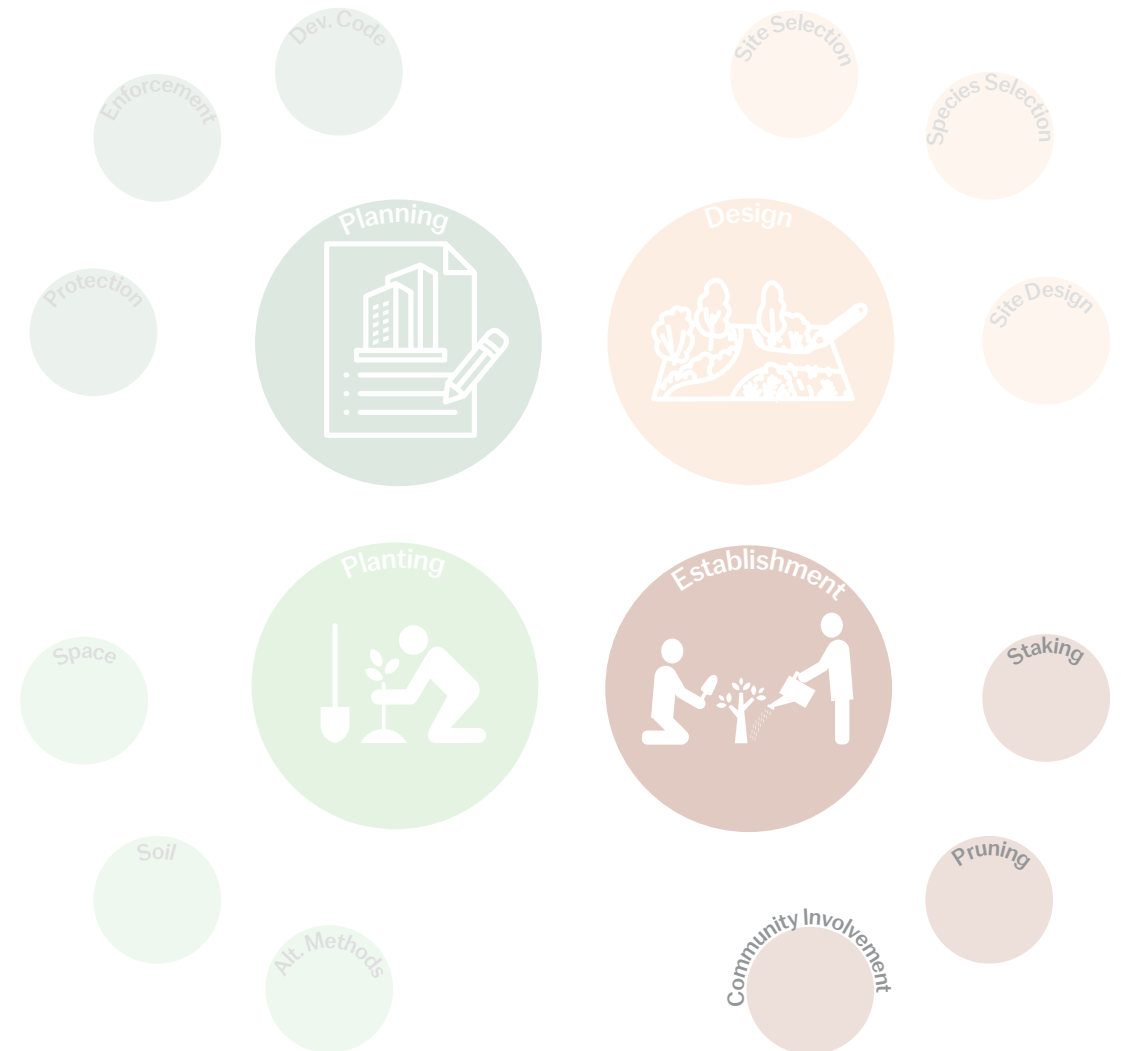


Soil cells offer a suspended pavement system to maximize uncompacted soil volume underground. It is important to provide adequate protective area at the surface level around each tree's trunk, while providing structural soil cells belowground to offer ample root space for one or more large shade trees. These soil cells will keep pavement, vehicles, and pedestrian traffic from further compacting the planting soil, and allow irrigation and air to adequately flow through the soil to the roots.



Figure 4.44 Honeylocust trees after five growing seasons in Silva Cells at Union Plaza in Lincoln, Nebraska (Sutton 2021).

Part 4: Establishment and Maintenance



Establishment

The establishment period of a street tree is the most crucial part of its life once planted and has the highest mortality rate (Lu et. al. 2010, 2; Roman et. al. 2014A, 23; Roman et. al. 2014B). When young, small caliper trees are planted in harsh urban conditions, maintenance and support are required for the first few years. Figures 4.44, 4.45, and 4.46 show the importance of providing space for toots to grow and staking and pruning guidance. Roman et. al. predicts that “financial resources would be better spent planting fewer trees, and investing more heavily in site modifications and tree care during the establishment phase to prevent high mortality of young trees” (Roman et al. 2014B, 399). Additionally, increasing the chances of survival during the establishment phase will reduce replacement needs, and extensive maintenance practices like pruning later down the line (Lu et. al. 2010, 2). Except during a drought, a well-established tree will not need irrigation as it grows older. The following techniques can lead to a healthy establishment period for an urban tree.



Figure 4.45 Young tree on Site One (Saunders 2024). Ample space is provided here for tree roots to grow and support good canopy growth. However, protecting the trunk from lawnmowers is also important.

Staking

Typically, staking isn’t needed if the tree and trunk are proportional, but James Urban provides reasons for staking(Urban 2008, 424). Better staking techniques include: “1) double staking without a high crossbar and one flexible tie to hold the tree upright, provide flexibility, and minimize tree injury; 2) triple staking; or 3) using sturdy stakes encircled with heavy wire or metal grillwork.” (Nowak et. al. 1990, 128).

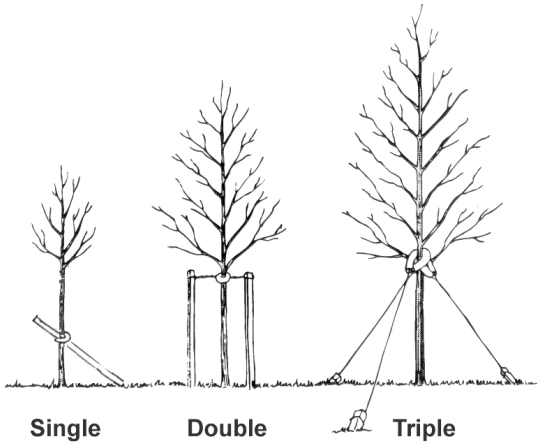


Figure 4.46 Examples of staking strategies depending on tree size (Wilson 2017).

Pruning

While excessive pruning is a major problem for mature trees, responsible pruning of young trees during the establishment period can increase growth rates, reduce irrigation needs, and reduce the needs for heavy pruning later in the tree’s life (Nowak et. al. 1990 129; Petri et. al. 2016, 109).

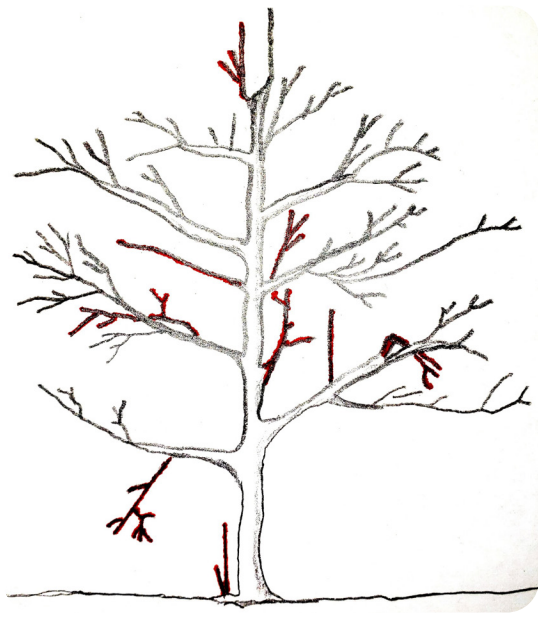


Figure 4.47 Diagram of necessary places to prune on a young tree (Bob's Market 2020).

Community Involvement

Boyce (2010) found that “expanding the definition of tree stewardship to include trained volunteers, stewards who can simply 'walk around' and recognize threats to the street trees can pay large benefits, if, and only if, such 'observational tree stewardship' is coupled with rapidly engaged professional tree rescue resources” (2010, 7). Follow-up by professional foresters paid for or supported by the city is very important.

When tree planting initiatives led by state or local agencies are partnered with willing and able community members, stewardship of the urban tree canopy is feasible. Civic stewardship and education initiatives influence the attitudes of residents and community members and can help foresters manage the urban canopy. Tree Pittsburgh, a tree planting initiative in Pittsburgh, Pennsylvania, is a good exmple of community engagement in care of their urban trees, shown in Figure 4.47.



Figure 4.48 'Tree Tenders' volunteering as part of the 'Tree Pittsburgh' initiative in Pittsburgh, Pennsylvania. (Tree Pittsburgh 2023).

Introduction

Design Intentions

To apply the design guidelines, two sites were selected to propose projective design concepts. Each site has two design concepts: One, which is a “conventional” scenario typical of current practices in Manhattan Kansas, meeting the minimum requirements for a residential development per the Development Code. The second proposal, which uses the same general

layout as the first one, implements the guidelines proposed in Chapter 4 of this report. The goal of these designs is to compare the current state of Manhattan Development Code to the potential changes in design choices influenced by the design guidelines. The intentions of the design are also to apply the findings of the tree-specific site assessment, and the study area analysis.

Site Selection and Context

Two sites were selected based on similar criteria to the other ten. Site 11 is in the Urban-Core Residential zone, while Site 12 is in High-Density Residential. This affects minor development requirements such as building size, lot size, and setback requirements. While the sites have not experienced new residential development in the last ten years (2012-2022) and have therefore not

experienced a significant loss in tree canopy, their location in these zones presents the possibility of such development.

Realistically, the entire block would not be developed at the same time, so Areas of Interest were defined, and lots with the potential for dwelling unit increases were selected for exploratory design proposals.

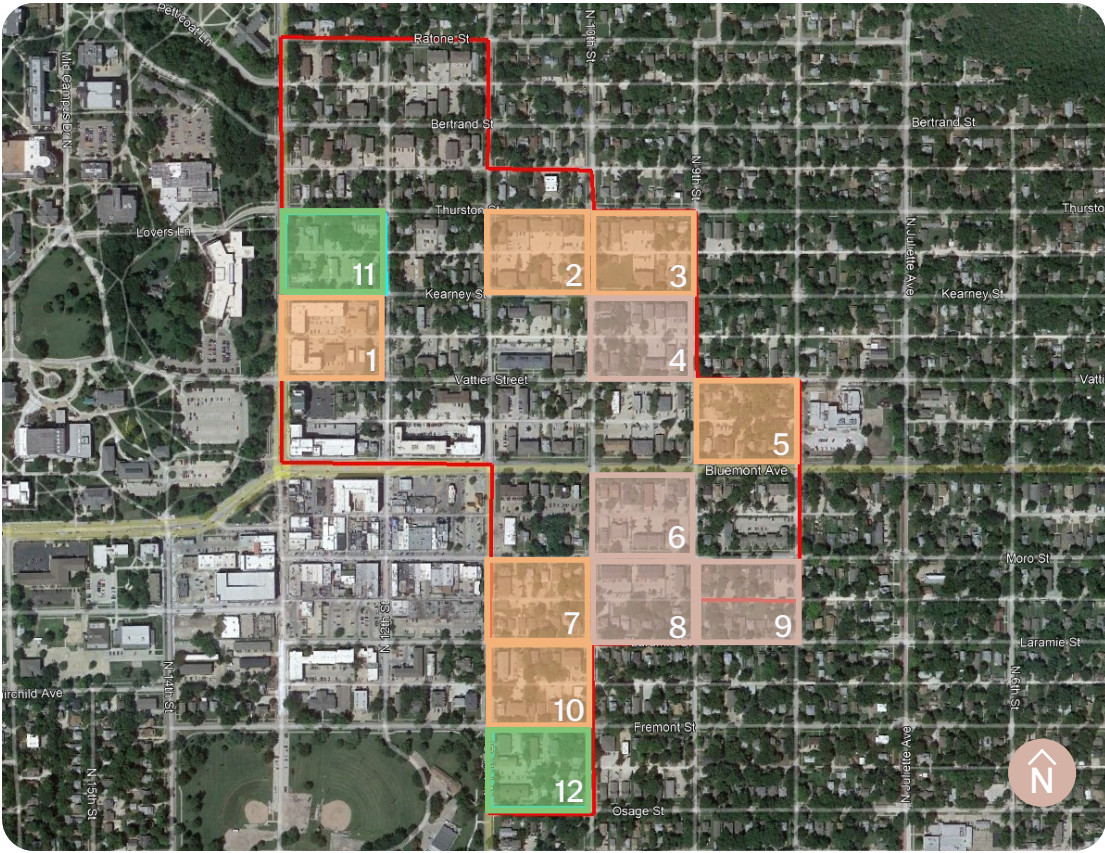


Figure 5.1 Projective Design site selection shown in green (Saunders 2024).

Introduction

Project Area Assessment

The measurements (impervious surface coverage, tree canopy coverage, and dwelling unit counts) conducted for the Study Area Analysis were replicated for the selected sites and used as a baseline metric. It was assumed that, even though the sites have not been densified in the last ten years, they will experience the same progression of tree canopy loss and dwelling unit increases that the ten sites in the study area did. The average tree canopy loss (33%), increase in impervious

surfaces (8.3%), and the increase in dwelling unit counts (30.6%) were applied to the first, “conventional” design proposal, with the goal of reflecting the current patterns of Manhattan, Kansas. The goal of the alternative proposal, with the application of the proposed guidelines, is to maintain the current tree canopy (or increase it) in the next ten years, while still increasing dwelling unit counts through development.

Tree-Specific Assessment

From the analysis of 104 trees in the study area, patterns were discovered related to potential causes for tree removal and mortality. For example, many trees were heavily pruned around power lines, balconies, sidewalks, and streets. Design decisions were made to avoid these types of conflicts, giving trees enough canopy space

by planting them farther away from buildings, and enough root space by decreasing the width of sidewalks and increasing the size of planting beds. Other findings from the assessment not only influenced the creation of guidelines, but directly affected design decisions.

Application of Guidelines

The design guidelines, as will be expanded on later in this chapter, were directly applied to the alternative proposals for each site. The focus lies mainly in the “Design” and “Planting” segments of the guidelines, as maintenance could not be fully addressed in the scope of the project.

Site Analysis

Manhattan Development Code Analysis

To ensure the relevance and applicability of this project to Manhattan, Kansas, the Development Code (shown again for ease of reference as Figure 5.2 to the right) was reviewed, and used rigorously during the design process. During this analysis, it was found that many sections of the code require more detail and specification, and the lack thereof (in combination with poor design, implementation, and maintenance practices) has resulted in the decrease in tree canopy coverage found during this study.

The lack of proper specification for tree protection, leniency in tree planting requirements, and an overwhelmed forestry department have led to the decrease in Manhattan's urban forest canopy and increased tree mortality. Nonetheless, the code was followed for the “conventional” design, and in some cases exceeded or expanded upon in the alternative proposal.

Development Code Requirement	Min./Max.
Curb Cuts	
Located to avoid removal of existing street trees.	yes/no
Street Trees	
1 overstory tree per 40 feet of street frontage.	1 / 40 ft. min.
Removed from the R.O.W. must be replaced as close to the location as practicable.	yes/no
Green Space	
Percentage of the site to be maintained as landscaped open space.	15% min.
Min. Plant Sizes and Varieties	
Overstory Trees	2.5 in. caliper
Understory Trees	1.5 in. caliper
Evergreen/Conifers	6 ft. tall
Shrubs	2 gal. container
Ornamental Grasses	1 gal. container
Min. Landscape Planting Requirements	
Building Foundations	
Next to and along no less than 30 percent of all building foundation lines that face or front a public street or private drive and not in a clearvision triangle area.	30% min.
Street Trees	
Within the tree lawn of a street right-of-way and not in a clear vision triangle area.	yes/no
One overstory tree (minimum 10' tall) for every 50' of street frontage, excluding driveways.	
Off-Street Parking Areas	
All rows of parking must be terminated with a curbed landscaped island.	9'x16' min.
Max. distance a tree can be from a parking space.	70' max.
Landscaping must be along at least 75% of the linear feet of frontage between the parking lot and the adjoining public street or private drive.	75% min.
All parking lot landscape islands must be landscaped with a combination of turf grass, prairie grass, plant beds, rock, wood chips, or shrubs, and trees.	yes/no
One overstory tree must be planted within each required landscape island.	1 overstory tree min.
Tree Preservation Credit	
6-12 in. caliper	3 overstory trees
12-24 in. caliper	4 overstory trees
24-36 in. caliper	5 overstory trees
>36 in. caliper	6 overstory trees

Table 5.2 Select Development Code table (Saunders 2024). Full table used during design process is located in Appendix 3.

Site Analysis: Site 11

Introduction

Site Eleven is located on North Manhattan Avenue and Thurston Street, across the street from Kansas State University. While the block is mainly residential, University for Man is a community learning center located on its northwest corner. On the southwest corner is a vacant lot that is currently being developed as of April 2024. The block is in the Urban Core Residential zone, meaning there is a potential for densification, particularly due to its proximity to the University.



Figure 5.2 University for Man (Saunders 2024).



Figure 5.3 Eastern redcedar on west side of Site Eleven (Saunders 2024).

There is a mix of multi-family and single-family homes, most of them occupied by renters. All of the homes on the block were built earlier than 2012, and therefore were not included in the Preliminary Site Analysis.



Figure 5.4 Site 11 Boundary (Saunders 2024).

Site Analysis: Site 11

Impervious Surface Coverage

60.1% of Site Eleven is covered by impervious concrete, or asphalt (Figure 5.5). This can propose challenging conditions for tree planting and longevity, as the soil underneath will be disturbed and compacted. With the current development on the southwest corner lot, this percentage is likely to increase.

Tree Canopy Coverage

Tree canopy covers 30.6% of the block (Figure 5.6). The goal of the alternative design is to either maintain or increase this coverage, as these trees provide environmental, social, and economic benefits to residents and community members in the area.



Figure 5.6 Diagram of impervious surface coverage on Site 11 (Saunders 2024). Total coverage is 60.1%.

60.1%



Figure 5.5 Diagram of tree canopy coverage on Site 11 (Saunders 2024). Total coverage is 30.6%.

30.6%

Lots and Dwelling Units

There are 63 total dwelling units on Site Eleven (Figure 5.7). This is less than typical for the Urban Core Residential zone, likely due to the vacant lot, and the presence of University for Man. To begin the site design, the highlighted lots in Figure 5.7 were chosen, including the vacant lots on the southwest corner. To reflect the increase in dwelling units across the project area, 43 new dwelling units were added in the design proposal, 19 of them representing the removed units in existing developments.

63 units



Figure 5.7 Dwelling unit counts for each lot on Site 11 (Saunders 2024). Total dwelling unit count is 63.

Site 11 Development: MHK Code Compliant

Site 11

The Manhattan, Kansas Code Compliant proposal includes a multi-family building with 43 units, a laundry room on each floor, and additional parking on the first floor (Figure 5.9). There are 9 proposed trees, along with 4 existing trees kept, and 6 trees removed. The proposal is typical of most multi-family development in the Urban Core Residential zone and proposes many trees that will likely not grow past establishment, due a lack of space and quality soil. The development meets the

minimums and maximums of Manhattan’s current Development Code, and the completed code table can be found in Appendix 2.

The alternative proposal (Figure 5.18) has 10 proposed trees, 5 existing trees kept, and 5 trees removed. By providing more space and alternative planting methods, the alternative proposal displays the same number of dwelling units as the conventional one, and more trees.



Figure 5.8 Conventional Proposal located on Site 11 (Saunders 2024).



Figure 5.9 Layout of the Proposed Site 11 Structure (Saunders 2024). The proposed structure contains 41 1-bedroom units throughout 5 floors, a laundry room, and additional parking on the first floor.



Figure 5.10 Mature tree diagram for the Conventional Proposal (Saunders 2024). Proposed trees are shown at their estimated mature size. Section line locations for the two sections shown on page 137 are noted on this plan diagram.

Soil Volume Provided

To accurately convey the resources being allocated to each tree in this proposal, the soil volume provided for each tree in each planting bed was calculated (Figure 5.11). As stated in Chapter 4, the area of the tree canopy multiplied by three feet of depth is a good formula to use when deciding how much volume a tree may need (Urban 2008, 94). Figure 5.11 shows the soil volume required for each tree highlighted in the green text box, with the actual soil volume

provided shown in black font. For example, a tree with a diameter of 15 feet (or an area of 176 square feet) would require at least 528 cubic feet of soil. However, in this proposal, trees are being provided with as little as 367 cubic feet in the parking islands. Therefore, it is not likely that the trees in this design will grow to their full projected canopy size and are at risk of mortality in the near future, depending on the quality of planting methods and ongoing maintenance.

2,782 ft.²
In Proposed Tree
Canopy Coverage

7,236 ft.³
Soil Volume Provided

Legend

- Soil Volume Provided
- (Soil Volume Required)



Figure 5.11 Amount of soil volume provided in each planting bed of Site Eleven's Compliant Proposal (Saunders 2024).

Section A-1 and B-1: Parking Islands

Figures 5.12 and 5.13 show typical planting medians required every 70 feet in a parking lot, per the development code. A 9'x16' planting bed does not provide enough space for a tree to reach its full maturity, especially when surrounded by impervious paving. The typically accepted method of tree planting is balled-and-burlapped which, if done incorrectly (for example burlap may be left around the top and sides of the root ball, constraining root growth), can result in girdling roots and short-lived trees.



Figure 5.12 Section A-1
(Saunders 2024).

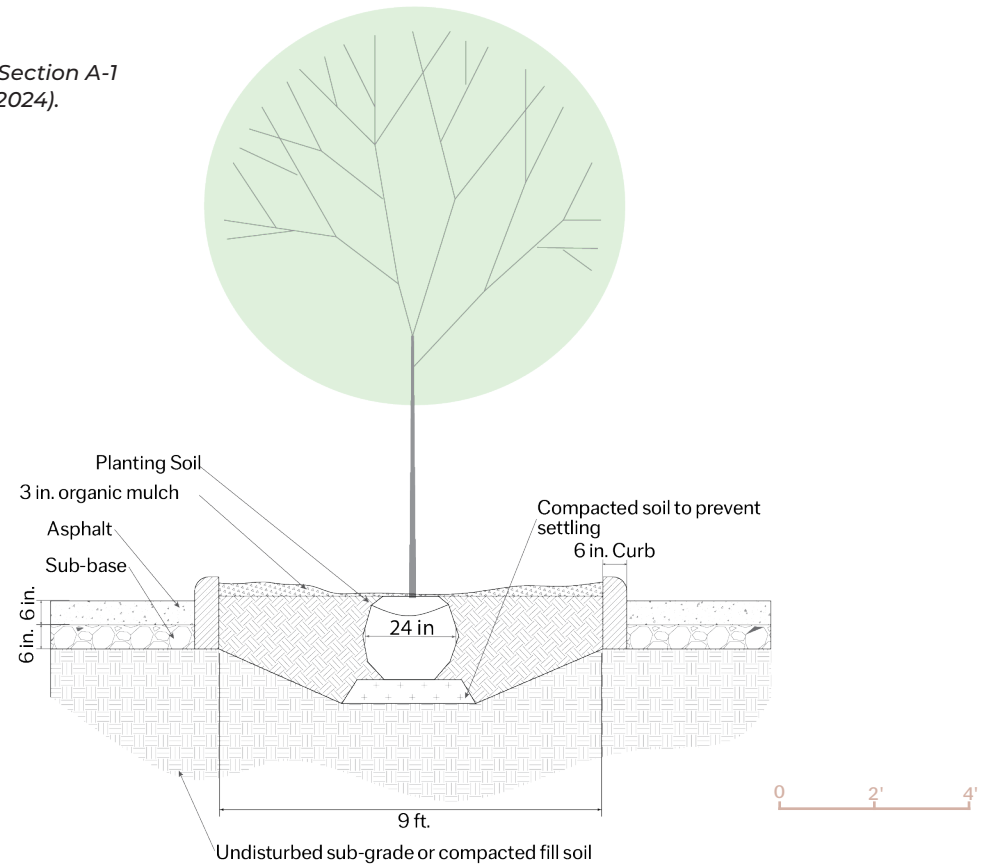
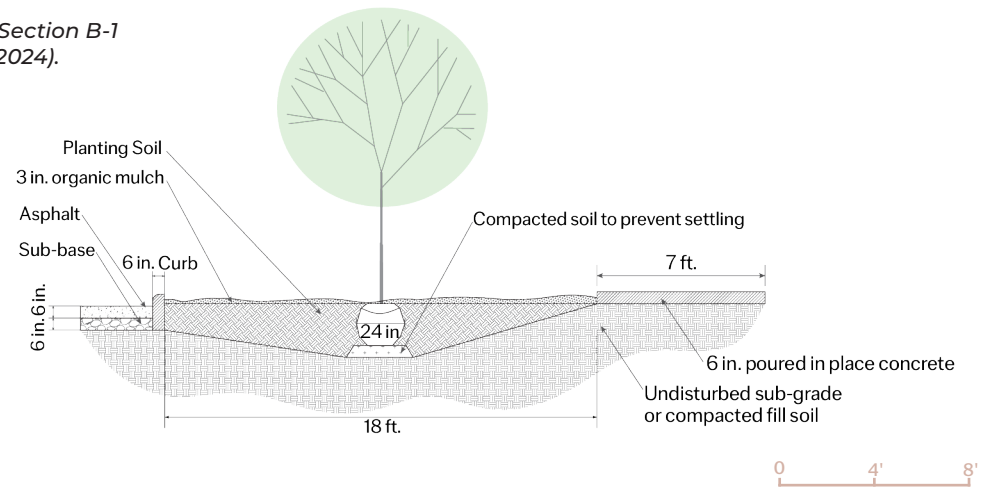


Figure 5.13 Section B-1
(Saunders 2024).



Species Selection

Code Compliant

Using the list of Preferred Trees for Northeast Kansas is typical for developers and designers (2018). Additionally, Manhattan prohibits the use of certain weak-wooded, fast-growing trees such as silver maple, or fruit trees that can pose a nuisance. Manhattan also requires overstory trees to be planted at 2.5 inch caliper and understory trees at 1.5 inch caliper. In the parking medians, goldenrain tree (Figure 5.14) and crabapples (Figure 5.15) are proposed.

Goldenrain tree is considered invasive, but is accepted on the list of Preferred Trees for Northeast Kansas, so it was used for its ornamental value. Osage orange (Figure 5.17) and bur oak (Figure 5.16) are also proposed, in areas that provide more room for them to grow larger, and they can grow in both drought and wet soils. Likely none of these trees will grow to their full maturity, as the soil volume required for longevity is not provided by the conventional site design.



Figure 5.14 Top left: Goldenrain tree (Lavin 2022).
Figure 5.15 Top right: Crabapple (Eminov 2014).
Figure 5.16 Bottom left: Bur oak (National Parks Gallery 2010).
Figure 5.17 Bottom right: Osage orange (Breen).

Site 11 Development: Alternative



Figure 5.18 Alternative Proposal located on Site 11 (Saunders 2024).



Figure 5.19 Mature tree diagram of the Alternative Proposal (Saunders 2024). Proposed trees are shown at their estimated mature size. Section line locations for the sections shown on pages 145, 146, 147 are noted on this plan diagram.

Soil Volume Provided

Different than the compliant proposal, many interventions are proposed to help tree roots grow into adequate soil provided to them. Soil cells (Figure 5.20) provide an extra 7,926 cubic feet of soil to trees in the parking lots. Coupled with pervious pavers, these trees will be provided with the proper aeration and space for their roots to grow without damaging the adjacent pavement. Filtered stormwater will also be provided as it moves down through the permeable paving.

6630 ft.²
In Proposed Tree
Canopy Coverage

Additionally, as will be discussed by Section C-1 (Figure 5.24), root paths and barriers are provided where tree roots may grow under pavement to reach extra soil volume. Overall, the alternative proposal will provide triple the amount of tree canopy coverage on the site by providing adequate amounts of quality soil volume.

19,516 ft.³
Soil Volume Provided
11,590 ft.³
Above-Ground
7,926 ft.³
Soil Cells

Legend

- Soil Volume Provided
- (Soil Volume Required)
- Proposed Soil Cell Area



Figure 5.20 Amount of soil volume provided in each planting bed of Site Eleven's Alternative Proposal (Saunders 2024).



Section A-2: Parking Islands

Very different from the conventional design, shown in Section A1, Section A2 (Figure 5.21) provides more soil volume, as well as amended soils to provide nutrients to the newly planted tree. These actions will allow the tree to grow to its projected maturity and provide shade to the adjacent sidewalk and parking stalls.

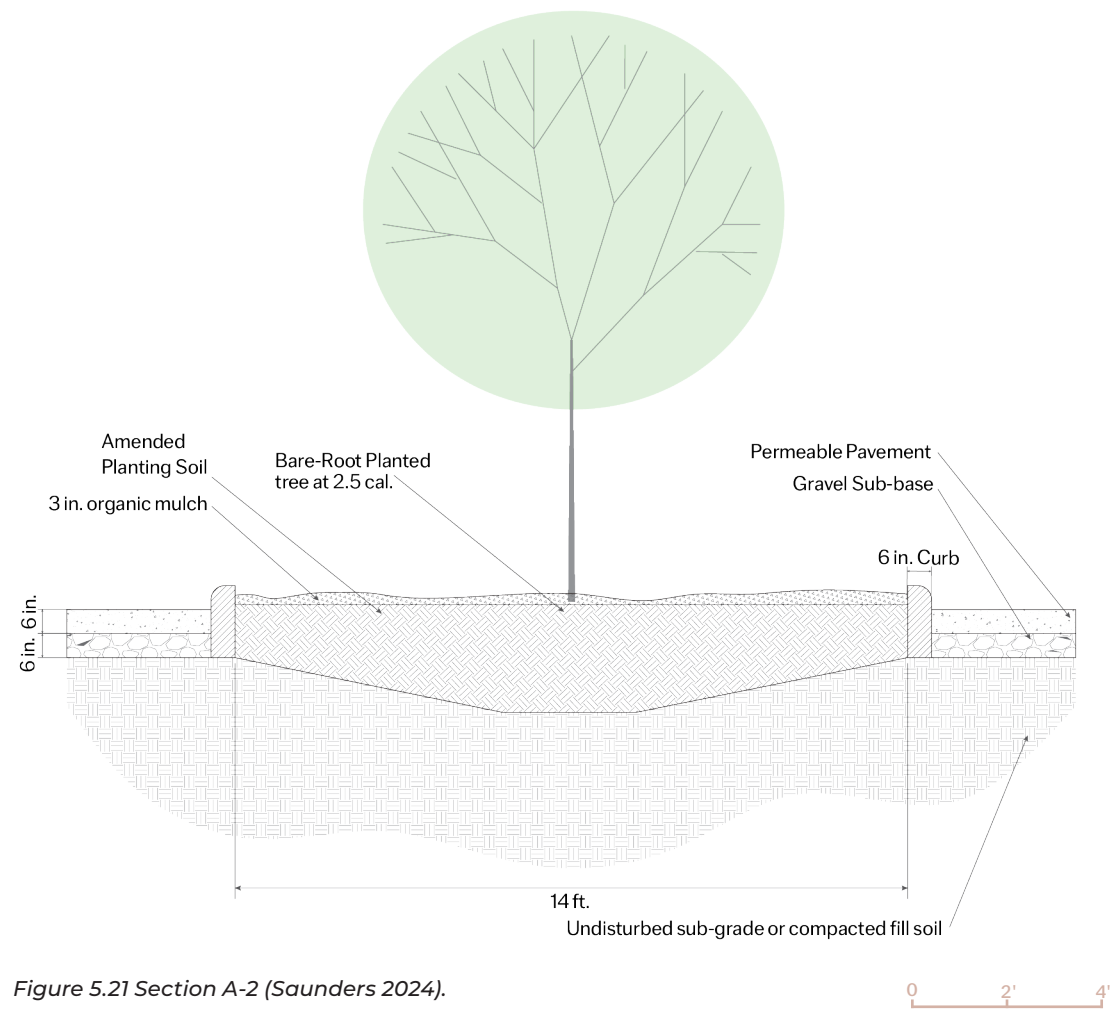
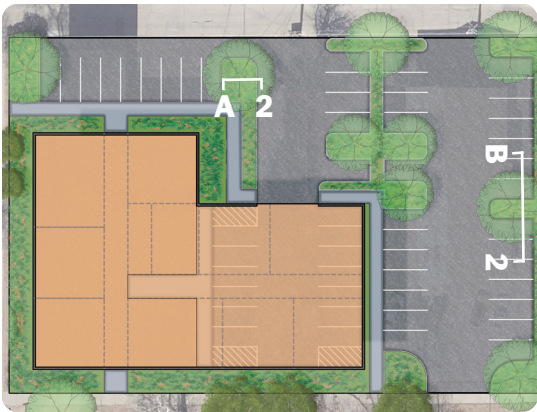


Figure 5.21 Section A-2 (Saunders 2024).

Section B-2: Soil Cells

In a challenging site mostly dominated by parking, it is important to provide underground root space for the proposed tree to grow to its projected size. Soils cells shown in Section B-2 (Figure 5.22) provide that soil volume to the eastern half of the parking lot on the site (Figure 5.20). This total soil volume is shared by six proposed trees, allowing them to grow to their full size (Figure 5.23).

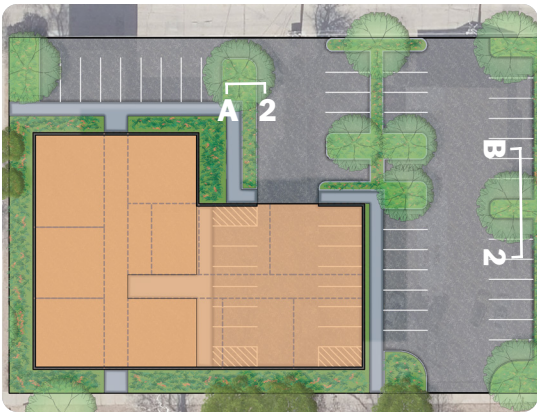


Figure 5.22 Section B-2
(Saunders 2024).

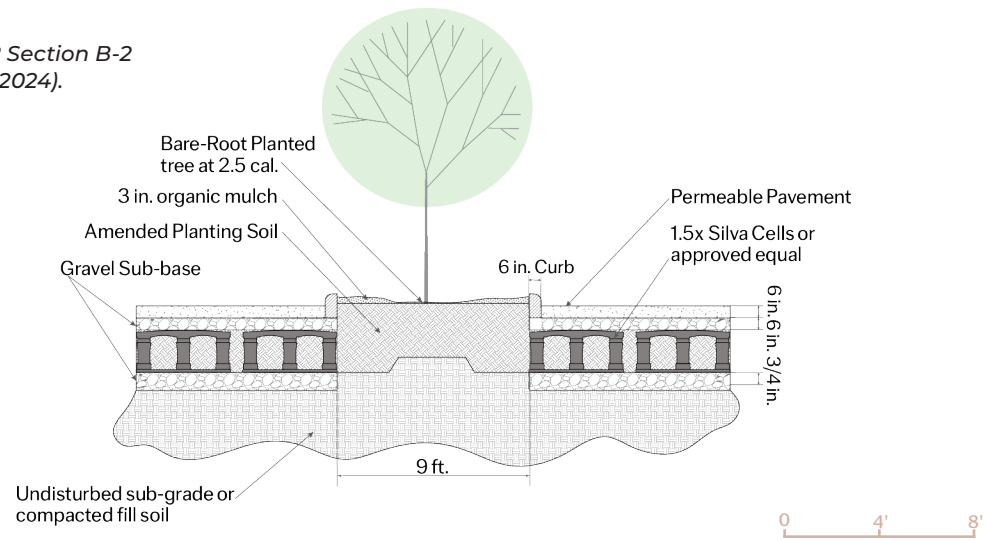
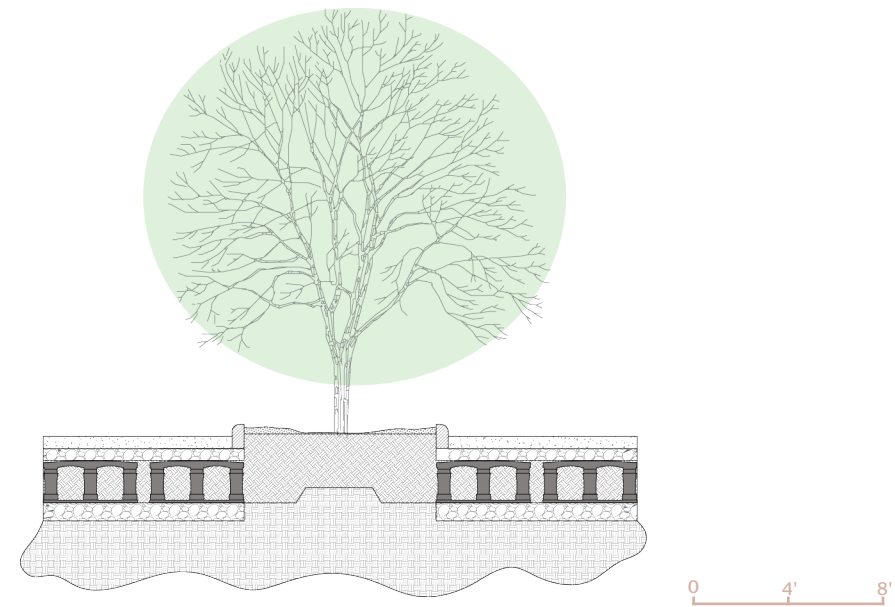


Figure 5.23 Section B-2 at
maturity (Saunders 2024).



Section C-1: Root Paths

Street trees are an important public amenity, and none are proposed in the conventional design. This is because, per the development code, existing trees can contribute to building street frontage minimums, so it was not required to plant any on the site. In the alternative proposal two street trees are inserted. To ensure they do not damage the sidewalk or curb, root paths are provided from the street tree lawn to the 10-foot planting bed outside of the proposed structure (Figure 5.24).

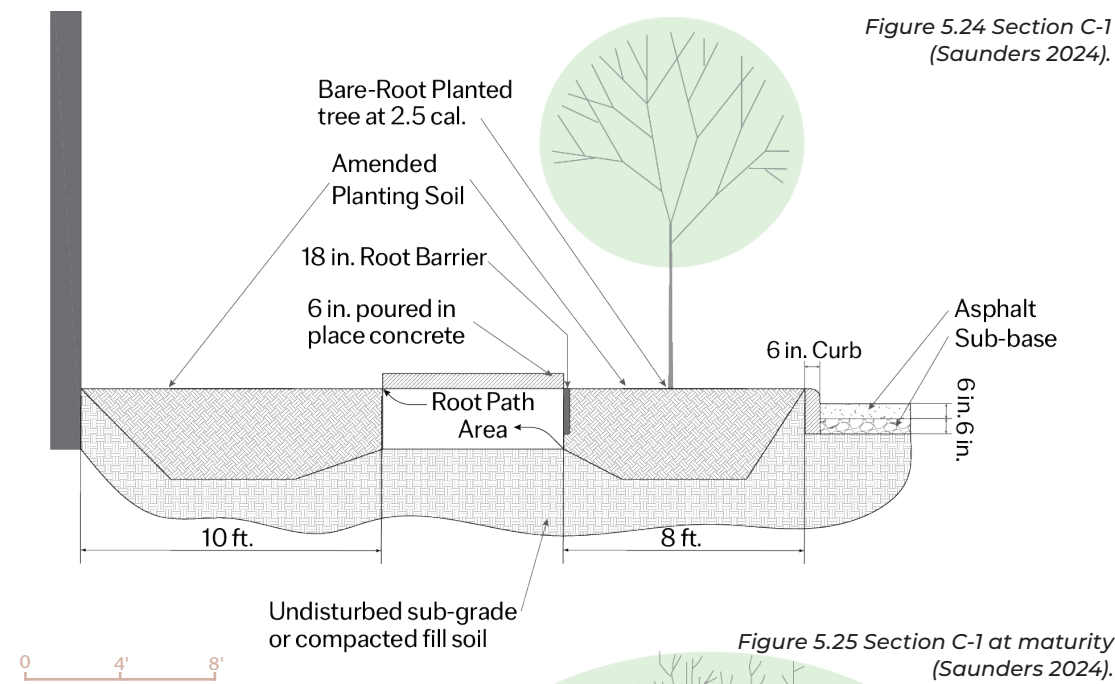


Figure 5.24 Section C-1 (Saunders 2024).

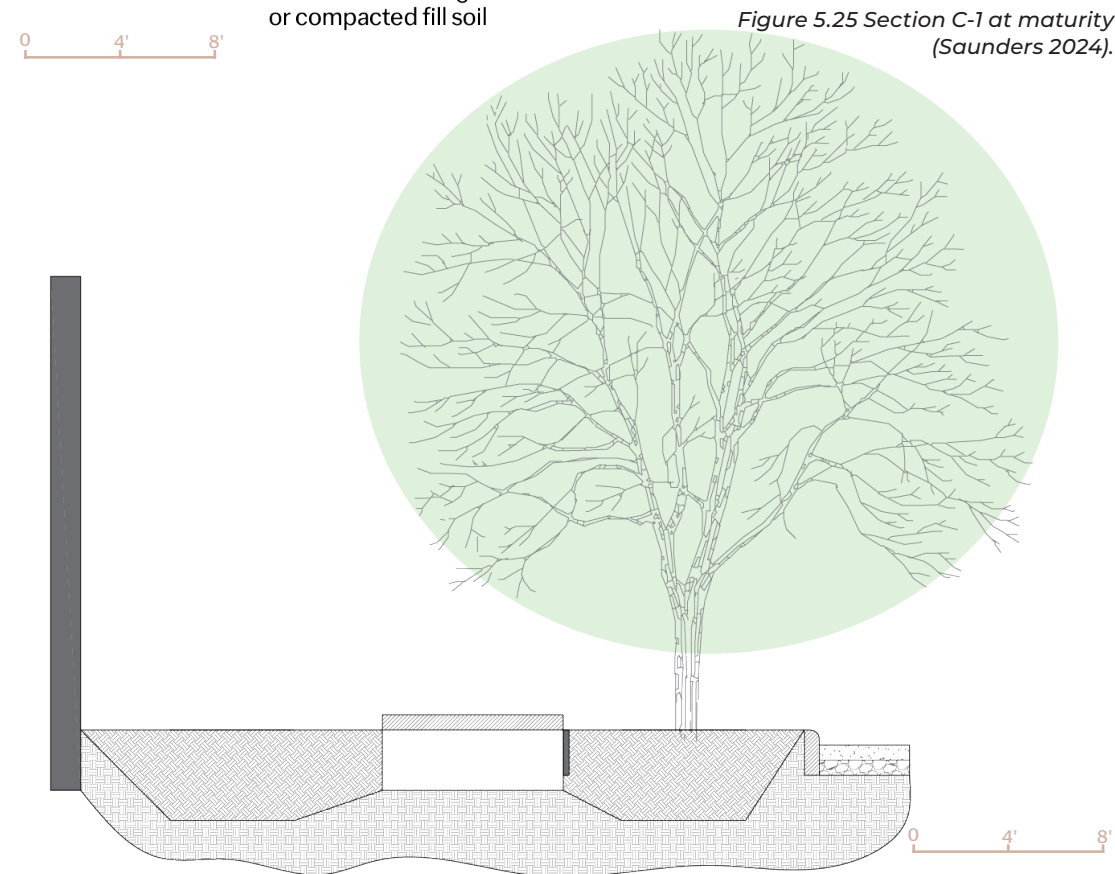


Figure 5.25 Section C-1 at maturity (Saunders 2024).

Species Selection

Alternative

For both alternative proposals, the “Trees and Shrubs for Difficult Sites” list provided by the Kansas Forest Service was used along with the “Preferred Trees for Northeast Kansas”, due to the challenging nature of Site Eleven. The current development code requires overstory trees, defined as 30 feet wide at maturity in every proposed landscaped parking island in a residential development. If a tree is supposed to reach its “overstory” status, as required, the soil volume required cannot be provided by a 9’x16’ parking median, the minimum per the development code.

Even with the alternative planting methods used in the alternative design, it may be better to propose smaller “understory” trees that can thrive in less soil volume where space is restricted. Therefore, eastern redbud (Figure 5.16) and a thornless variety of cockspur hawthorn (Figure 5.29) are proposed in the parking medians. Bur oak (Figure 5.28) and swamp white oak (Figure 5.27) are proposed as well, away from sidewalks and parking areas to avoid conflicts with large acorns. These trees can survive in challenging urban conditions, and with the soil volume provided in the site design, these trees would be expected to grow to their full maturity.



Figure 5.26 Top left: Eastern redbud (Famartin 2021).
Figure 5.27 Top right: Swamp white oak (James St. John 2021).
Figure 5.28 Bottom left: Bur oak (National Parks Gallery 2010).
Figure 5.29 Bottom right: Thornless cockspur hawthorn (Plant Image Library 2017).

Site Analysis: Site 12

Land Use: Site 12

Site Twelve (Figure 5.32) is located on 11th and Fremont Street, close to Manhattan City Park. The block is entirely residential, located in the High Density Residential zone. There is a high presence of parking lots, and while the current Development Code was likely put into place after

these residences, none of the parking lots provide the required trees or parking islands described in the code, and there is a need for street trees on the northwest corner. Like Site Eleven, there is a mix of single-family and multifamily homes, with most of them being renter-occupied.



Figure 5.30 Newly-implemented bike lane and sidewalk on northwest corner (Skabelund 2024).



Figure 5.31 Apartment buildings and street trees on Site Twelve (Skabelund 2024).



Figure 5.32 Site Twelve Boundary (Saunders 2024).



Site Analysis: Site 12

Impervious Surface Coverage

Similar to Site Eleven, 57.3% of Site Twelve is covered by impervious surface (Figure 5.33). As previously stated, there is a major lack of parking lot trees, which would be required to combat the environmental effects of that much pavement.

Tree Canopy Coverage

The tree canopy coverage of Site Twelve is 25.1%, with most of the trees being located on the west side of the block, where mostly single-family homes are located (Figure 5.34). There is a lack of trees planted in the existing parking lots, and with the newly implemented bike lane on the east side of the site replacing the typical 8-foot tree lawn, there is a lack of street trees.



Figure 5.34 Impervious surface coverage on Site 12 (Saunders 2024). Total coverage is 57.3%.

57.3%



Figure 5.33 Tree canopy coverage on Site 12 (Saunders 2024). Total coverage is 25.1%.

25.1%

Site Analysis: Site 12

Lots and Dwelling Units

There are 96 total dwelling units on Site Twelve. The selected lots are highlighted in Figure 5.35 and were chosen because of the opportunity for an increase in density. To reflect the overall increase in density across the project area, 28 dwelling units were proposed, ten of them replacing the existing units.

86 units



Figure 5.35 Dwelling unit counts for each lot on Site 12 (Saunders 2024). Total dwelling unit count is 86.



Site 12 Development: MHK Code Compliant

Site 12

The proposed design (Figure 5.36) consists of multifamily housing with 28 units (Figure 5.37) and a courtyard. The units consist of 30'x30' one-bedroom apartments, typically used by students at Kansas State University living in the area. In the conventional proposal, seven trees were proposed, four existing trees were kept, and six trees were removed. Like the Conventional Proposal for Site Eleven, the trees proposed in this design will likely not grow past establishment due to a lack of quality soil volume and above-ground space for growth of the canopy.

In the alternative design (Figure 5.46), nine trees were proposed, five existing trees were kept, and five trees were removed. No complex methods are proposed in this alternative. Importantly, responsible species selection and substantially more space for root growth are provided. A large, mature tree in the middle of the site was preserved to provide significant shade to the proposed courtyard.



Figure 5.36 Conventional Proposal located on Site 11 (Saunders 2024).

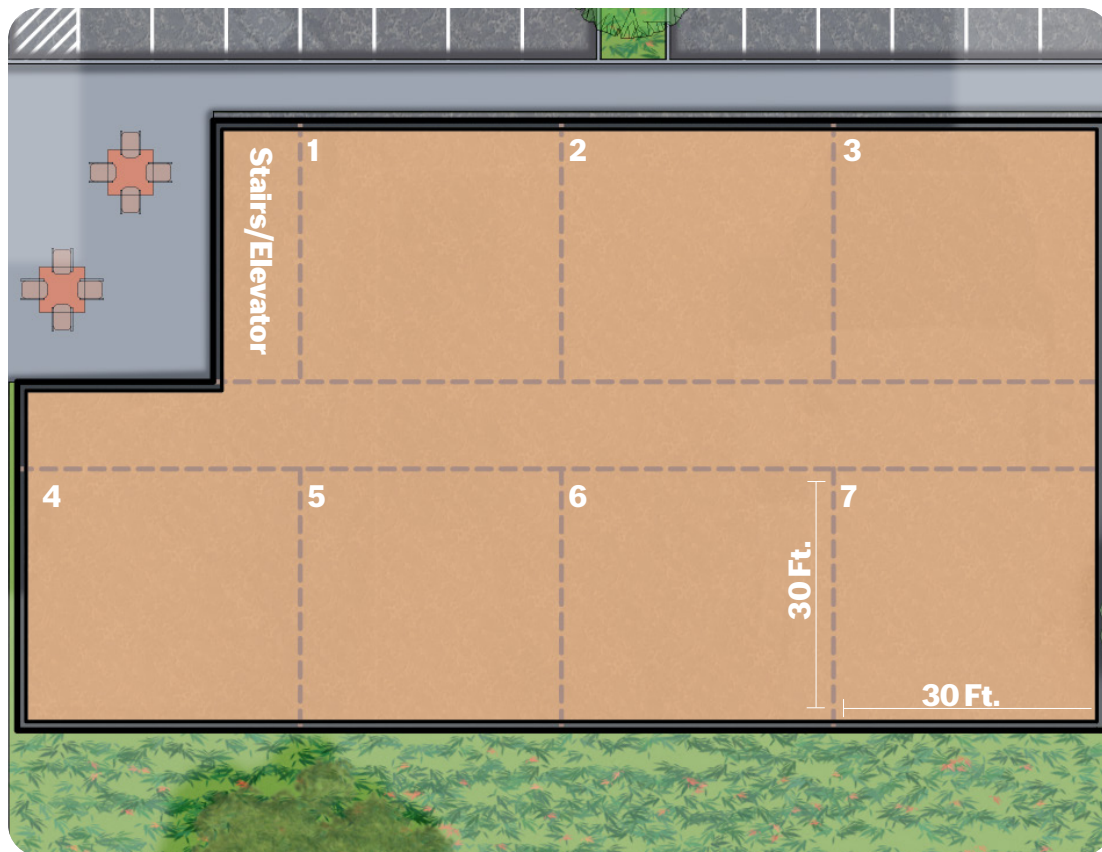


Figure 5.37 Layout of the Proposed Site 12 Structure (Saunders 2024) The proposed structure contains 28 1-bedroom units, throughout 4 floors.



Figure 5.38 Mature tree diagram of the Conventional Proposal for Site 12 (Saunders 2024). Proposed trees are shown at their estimated mature size. Section line locations for the sections shown on pages 165 are noted on this plan diagram.

Soil Volume Provided

As discussed in the code-compliant Conventional Proposal for Site Eleven, the required soil volumes for each tree were once again compared to the actual soil volume provided to each tree proposed. In some cases, trees were not provided with the minimum amount of soil volume needed, based on the formula provided by James Urban (Urban 2008, 94). While 3,372 square feet of tree canopy coverage is proposed on the site, at least three trees are at risk of mortality due to inadequate soil volumes and the harsh environment of this urban site.

3,372 ft.²

In Proposed Tree Canopy Coverage

17,727 ft.³

Soil Volume Provided

Legend

Soil Volume Provided

(Soil Volume Required)

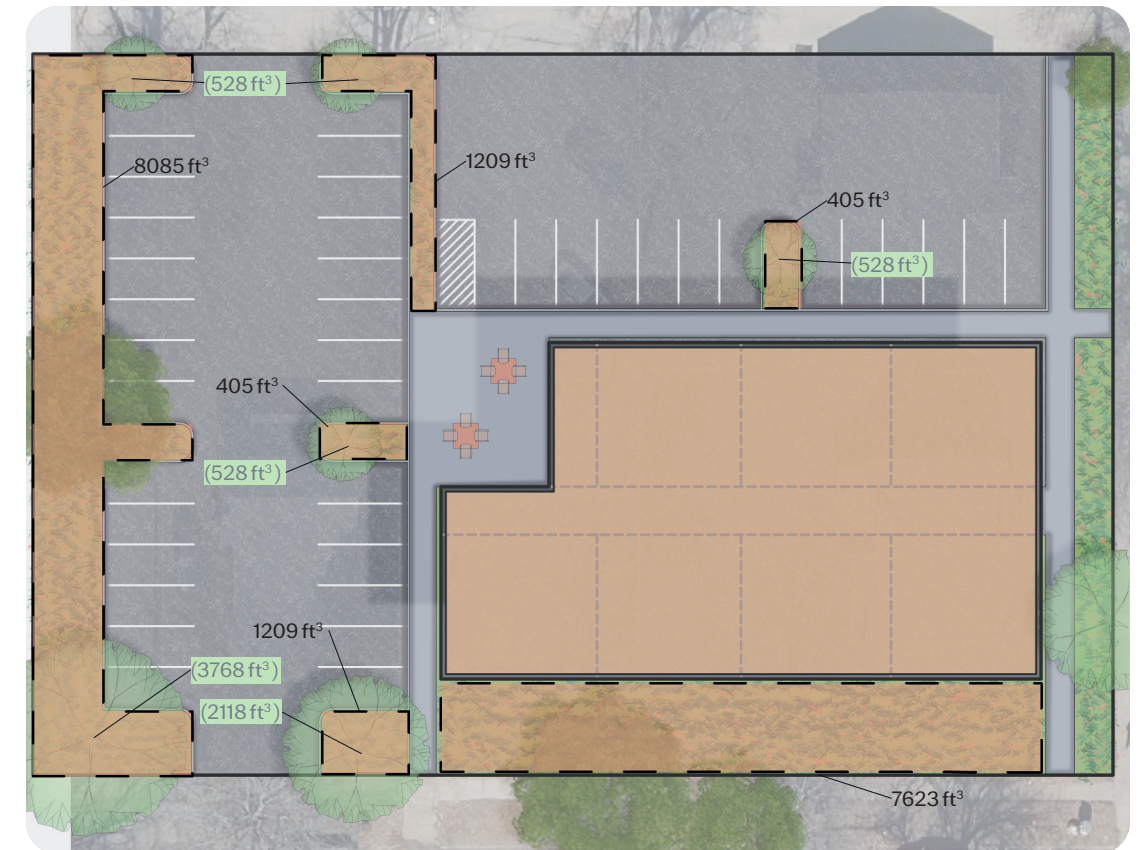


Figure 5.39 Amount of soil volume provided in each planting bed of Site Twelve's Conventional Proposal (Saunders 2024).



Section E-1 and F-1: Parking Islands

Per the current Manhattan, Kansas Development Code, typical parking medians are proposed throughout the site (Figures 5.40 and 5.41). Because these trees are surrounded by hardscape and structure, these trees will likely not grow to provide a significant amount of shade or manage a significant amount of stormwater. The tree in Figure 5.40 is meant to replace a large, mature tree, and the canopy from that tree was lost.



Figure 5.40 Section E-1 (Saunders 2024).

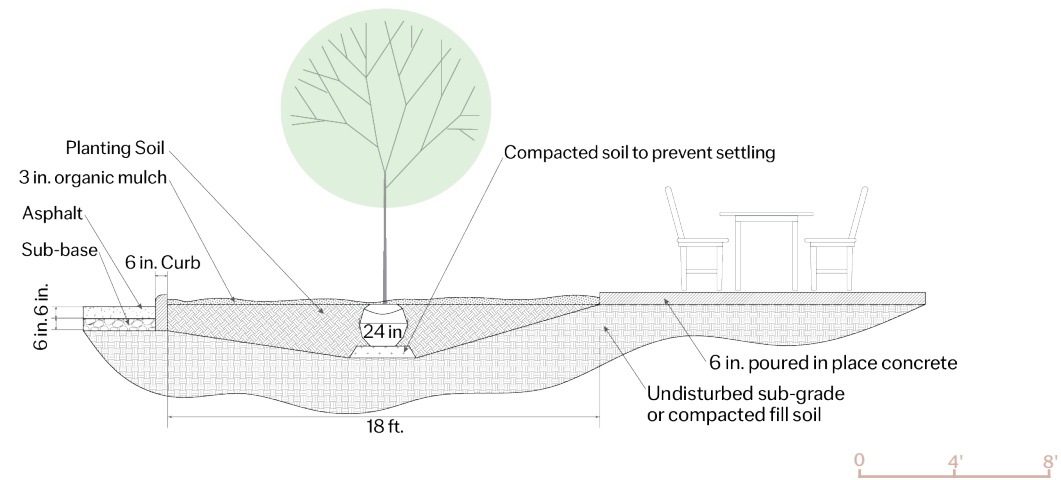
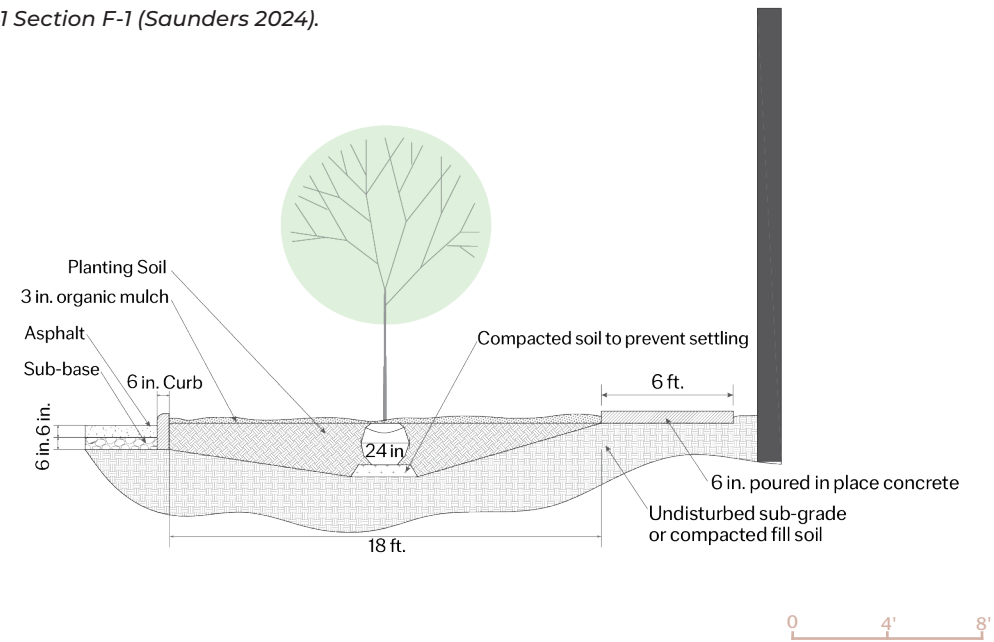


Figure 5.41 Section F-1 (Saunders 2024).



Species Selection

Code Compliant

Using the same rationale as the Conventional Proposal for Site Eleven, seven trees were selected using the list of Preferred Trees for Northeast Kansas (2018). Goldenrain tree (Figure 5.42) and Amur maples (Figure 5.45) are proposed in the parking lot, with red oaks (Figure 5.43) and pin oaks (Figure 5.44) proposed on the street frontage. Although Amur maple and

goldenrain trees are considered invasive in some areas, these two species are still acceptable per the list of Preferred Trees in Northeast Kansas, and the Manhattan Development Code. With the high number of existing oaks on the site, this species selection will match the character of the neighborhood and Manhattan as a whole.



Figure 5.42 Top left: Goldenrain tree (Lavin 2022).
Figure 5.43 Top right: Red oak (Sontag 2007).
Figure 5.44 Bottom left: Pin oak (Richards 2012).
Figure 5.45 Bottom right: Amur maple (Family Tree Nursery 2019).

Site 12 Development: Alternative



Figure 5.46 Alternative Proposal located on Site 12 (Saunders 2024).

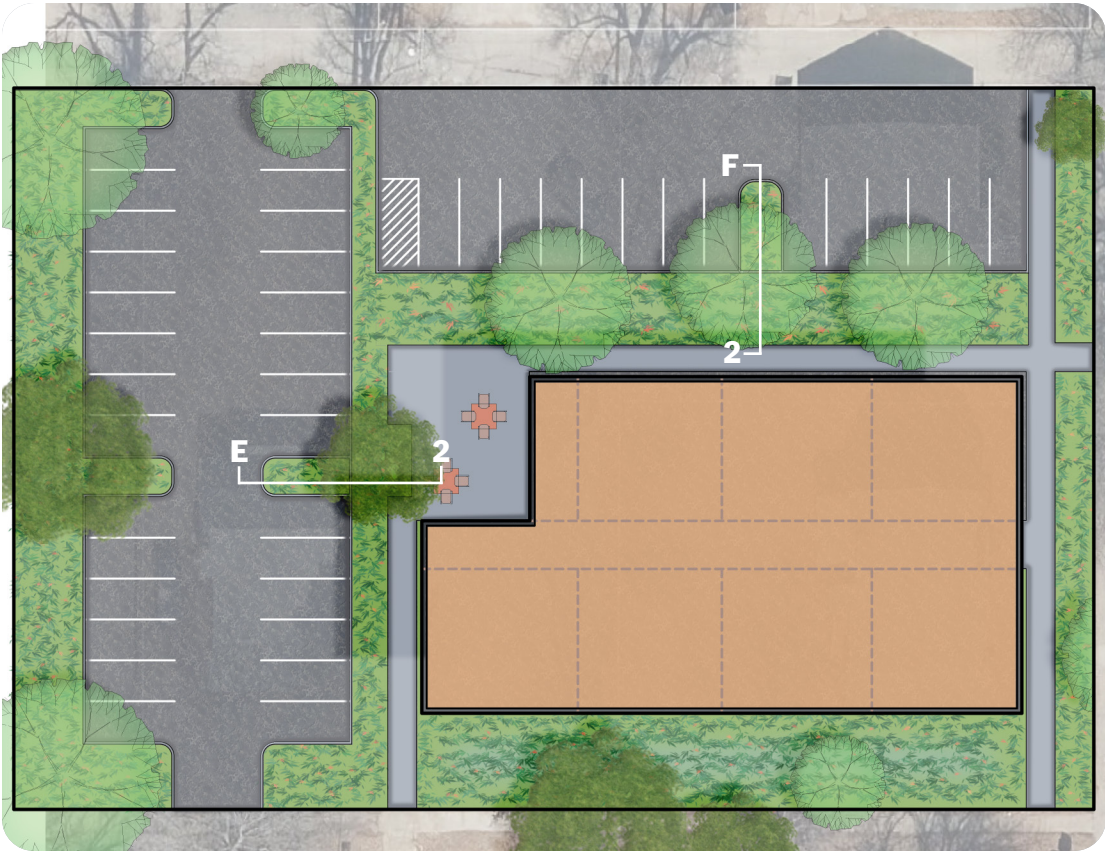


Figure 5.47 Mature tree diagram for Alternative Site 12 Proposal (Saunders 2024). Proposed trees are shown at their estimated mature size. Section line locations for the sections shown on pages 173 and 175 are noted on this plan diagram.



Soil Volume Provided

By simply allocating more space to each tree in the Alternative Proposal for Site Twelve, the trees can be expected to grow larger and to live longer. Additionally, an existing mature tree could be preserved. Soil cells, root paths, and other alternative methods were not necessary in this case, as simple design interventions could be

made to ensure that adequate soil volume was provided. As a result, 10,000 cubic feet of soil volume were added compared to the compliant proposal, resulting in double the proposed tree canopy coverage. It is important to note that existing tree canopy coverage was not included in this calculation.

6,278 ft.²
In Proposed Tree
Canopy Coverage

27,063 ft.³
Soil Volume Provided

Legend

- Soil Volume Provided
- (Soil Volume Required)



Figure 5.48 Amount of soil volume provided in each planting bed of Site Twelve's Alternative Proposal (Saunders 2024).



Section E-2: Tree Protection

Protecting existing mature trees during the site design process can preserve the existing tree canopy, and an already-established tree provides more benefits to a site than a newly-plant, young tree. The tree planting area was expanded to prevent the removal of the tree in Figure 5.49 and allows it to provide shade and aesthetic value to the adjacent courtyard.

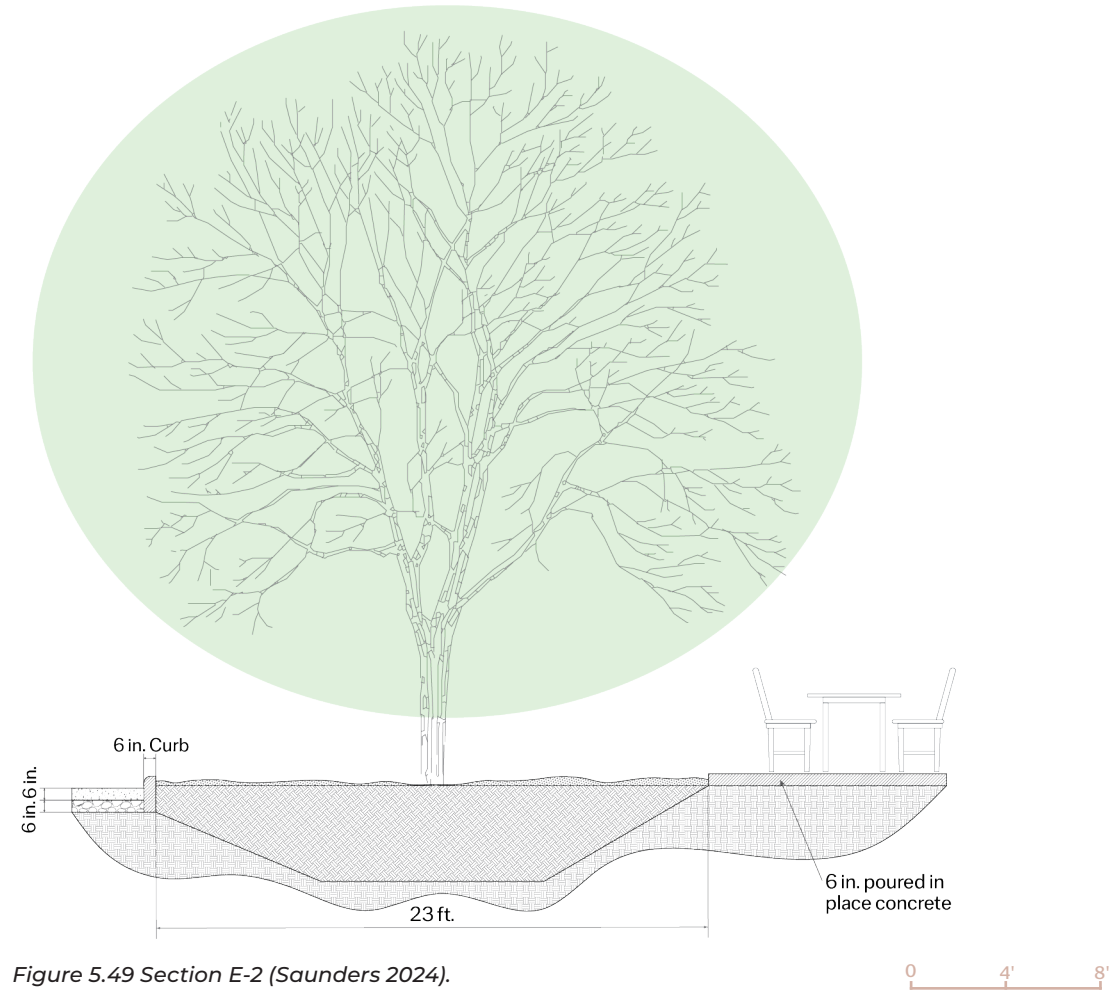


Figure 5.49 Section E-2 (Saunders 2024).

Section F-2: Tree Lawn

A 15-foot tree lawn was provided in the Alternative Proposal for Site Twelve (Figure 5.50). This provides the proper amount of soil volume for multiple trees to be planted as opposed to the conventional proposal. These trees provide benefits to the adjacent sidewalk and parking lot and are planted with the structure in mind to prevent any conflicts.

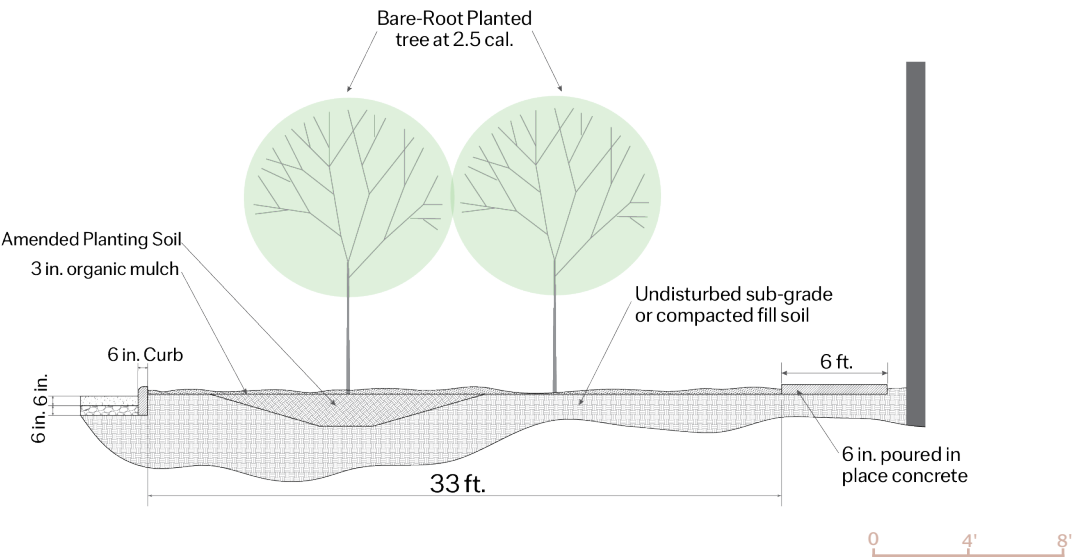
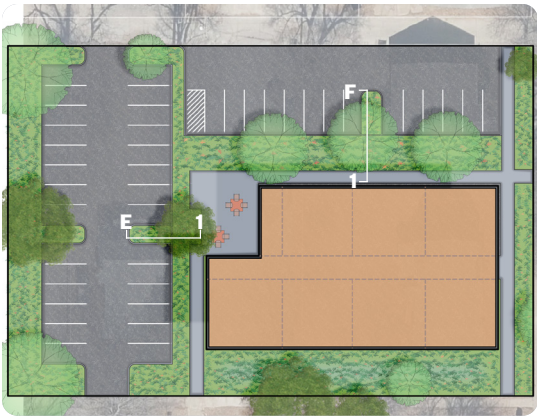
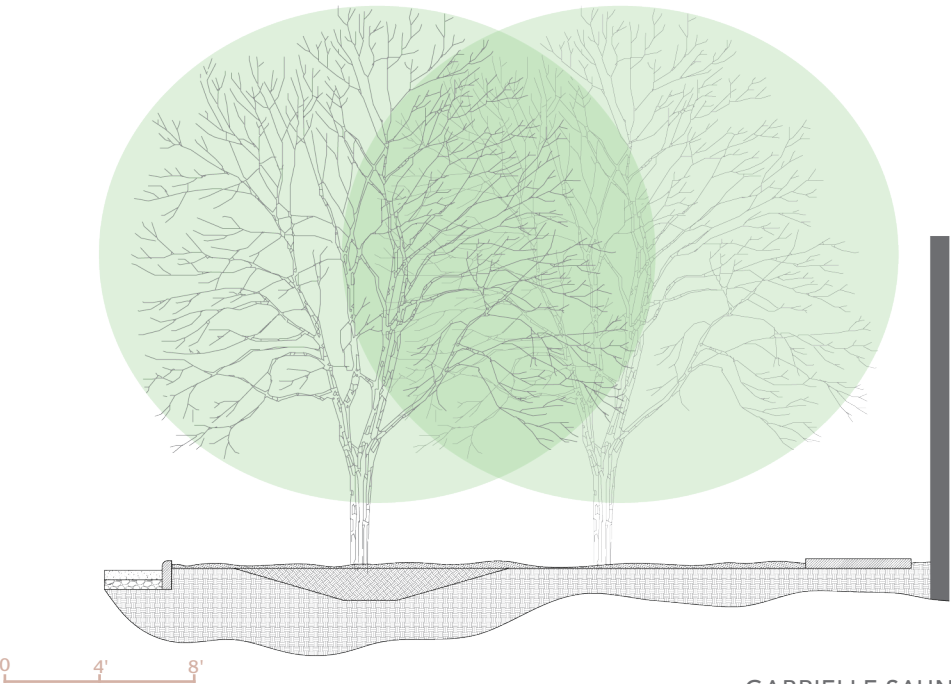


Figure 5.50 Section F-2 (Saunders 2024).

Figure 5.51 Section F-2 at maturity (Saunders 2024).



Species Selection

Alternative

Using the list of Trees and Shrubs for Difficult Sites provided by the Kansas Forest Service (Robinson 2006), trees with high wildlife value and canopy coverage were selected. It is expected that these trees will survive in the challenging conditions presented on Site Twelve. Eastern redbud (Figure 5.52) was proposed as parking

lot trees in the tree lawn on the north side of the building, with thornless honeylocust (Figure 5.53) as ornamental additions in the northern tree lawn, and London Planetree (Figure 5.54) and swamp white oak (Figure 5.55) on the site and street.



Figure 5.52 Top left: Eastern redbud (Famartin 2021).
Figure 5.53 Top right: Thornless honeylocust (Famartin 2020).
Figure 5.54 Bottom left: London Planetree (N Chadwick 2015).
Figure 5.55 Bottom right: Swamp white oak (James St. John 2021).

Answering Sub-Questions

How has densification in the last ten years impacted High-Density and Urban Core Residential zones in Manhattan, Kansas?

The Study Area Assessment, comparing characteristics of ten blocks in the Urban Core and High-Density Residential areas of Manhattan Kansas showed considerable changes in the last ten years (2012-2022). As dwelling units increased by 30.8%, because of densification through development in these zones, tree canopy coverage decreased by 33%.

Additionally, the Tree-Specific Site Assessment process showed the effects of new buildings and impervious surface increases on the urban tree canopy in these same areas. Buildings bigger and impervious surfaces have increased, creating smaller, more difficult planting areas for trees to grow in.

Which physical conditions present in the study area contribute to street tree mortality? Which are the most prominent?

Through the Tree-Specific Site Assessment three major conditions were found to prominently affect the street trees in the project area: excessive pruning, conflicts with buildings and sidewalks, and signs of suckers and shoots. Severe pruning practices can cause weight distribution issues, increased susceptibility to diseases, stunted growth, and has negative effects on the aesthetic characteristics of the tree.

Conflicts with surrounding infrastructure can cause damaged sidewalks and utilities, and are often the reasoning behind severe pruning practices. Lastly, as trees are not maintained, suckers, shoots, and an abundance of invasive Manhattan ivy are becoming more prominent in the study area.

Figure 6.1 Tree roots interfering with sidewalk (Saunders 2024).



Figure 6.3 Tree pruned around power lines (Saunders 2024).



Figure 6.2 Invasive Eastern redcedar and broken concrete (Saunders 2024). If left to grow, the redcedar will compete for scarce resources.



Figure 6.4 Tree roots lifting and cracking adjacent sidewalk (Saunders 2024).

Answering Sub-Questions

What are the current zoning/design guidelines regarding street trees in Manhattan, Kansas? Where can they improve to better ensure tree longevity?

Currently, Manhattan’s Development Code is underdeveloped and lacks the details needed to ensure that developers and designers have the correct guidance to ensure that trees are not only planted but maintained after planting. Oklahoma City’s Development Code should be referenced, and increasing the tree canopy

in Manhattan should be specified as a goal in the Comprehensive Plan. Minimum Landscape Requirements should require adequate soil volumes needed to support trees of the specified size, as well as design strategies (such as soil cells, root paths, tree guards, etc.) where that soil volume is difficult to attain.

What are the specific tree selection and planting strategies needed to ensure tree longevity? What contexts should they be applied in?

Better planning and updates to the minimum landscape requirements could improve the required planting and maintenance practices needed to keep trees alive and thriving. Additionally, consideration during the design process, and designing spaces for trees with the same amount of priority as sidewalks and other amenities is important. Collaboration between developers, landscape architects, soil scientists, planners, and community members is paramount

in the process of growing Manhattan’s tree canopy, and protecting the mature trees that make the city part of Tree City USA. Planting strategies such as soil cells, root paths, and better maintenance practices can also ensure that newly planted trees during development and densification have the proper support to contribute to the existing tree canopy and make it past the establishment phase of five years.

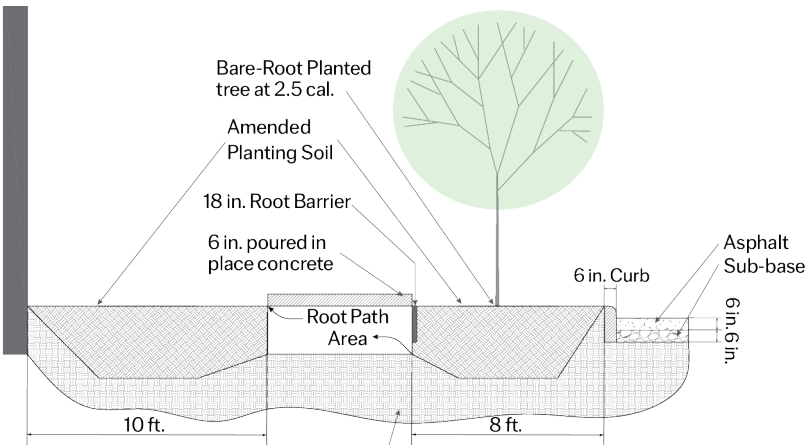


Figure 6.5 Section C-1 (Saunders 2024).

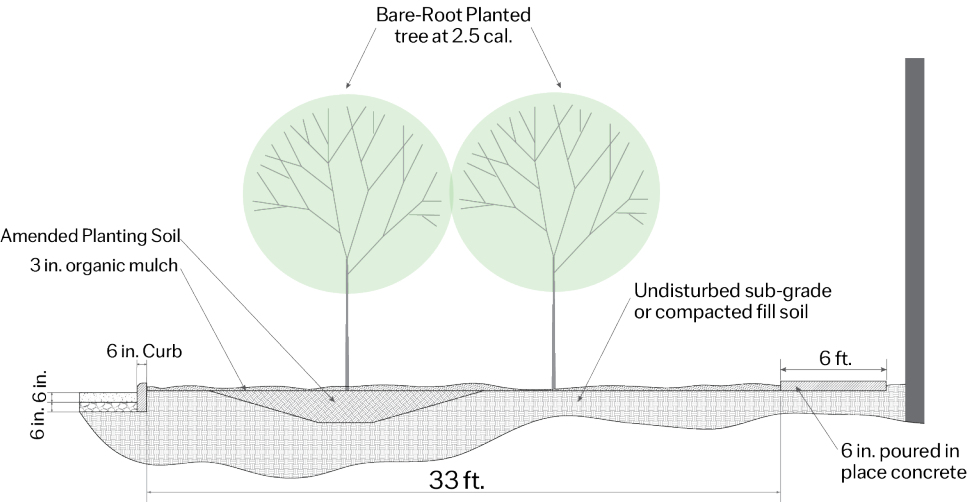


Figure 6.6 Section F-2 (Saunders 2024).

Continued Research

Further research would involve more exploration into the soil science aspect of tree health. Collaboration with soil scientists is required in the design process to amend urban soils and find suitable soil characteristics that tree species should be planted in. Additionally, a longer study with more funding could involve testing the planting methods mentioned in this study, such as different types of soil amendments, soil cells, and species selection.

Limitations

There were several limitations pertaining to this Master’s Report. Not only was time a factor in measuring the health of the existing street trees, but the trees were also evaluated in the winter when their canopy and leaves could not be evaluated. Additionally, the author did not have the tools or expertise to fully evaluate the conditions of the soil for each tree, or measure the compaction.

Another limitation in the design process was access to utility plans for the selected sites, which could pose potential issues with the placement of the trees. For example, if a tree was planted over a private phone line that was unknown to the author, it would certainly be a flaw in the design. Further consideration of these factors would be necessary if the designs were implemented in the future.

Personal Reflection

This project was the most challenging one I’ve ever done. Students in the years above me told me that there was always something more you wish you could have done, but I didn’t realize how right they would be. Throughout this academic year I’ve decided that this is one of my passions and something I want to incorporate into my future career, which is exciting and mysterious, and I hope to find people in the Landscape Architecture community with my same goals and intentions. Being the first person in my immediate family to go to college (let alone Graduate School) has been equally challenging, and I wouldn’t have been able to do it without their support. I’m grateful to my grandparents, who have been there to tow my half-broken car back to Wichita when it failed me and gave me a place to stay during my internship.

I’m grateful for my dad, who did everything he could to get me through college and kept me from dropping out after second year. I’m grateful for the abundant, loving circle of friends I’ve acquired, all the late nights we’ve had together, and the love I have given and received. I’ve worked incredibly hard throughout my career at K-State, but working at the Meadowlark Retirement community has fulfilled me equally throughout this journey (I wrote this reflection at the counter of Meadowlark’s Prairie Star Restaurant), and I’m incredibly grateful to have found such a supportive, welcoming environment full of people that have influenced me greatly. These past five years have fulfilled me in ways that I can only hope to replicate in my future, and I can only hope to find a community elsewhere as rich as the one I’ve found here.



Figure 6.7 Author at Hakgala Botanical Garden, Nuwara Eliya, Sri Lanka. (Gonzalez 2023).

References and Appendices

References

Bethesda: The Maryland-National Capital Park and Planning Commission. “Bethesda Downtown Plan.” October 2020. Accessed February 2024. https://montgomeryplanning.org/wp-content/uploads/2020/10/Approved-2020-Bethesda-Streetscape-Standards_FINAL100820.pdf

Boyce, Steven. 2010. “It Takes a Stewardship Village: Effect of Volunteer Stewardship on Urban Tree Mortality Rates.” *Cities and the Environment* 3 (1): 1-8. https://web.archive.org/web/20180602090313id_/http://digitalcommons.lmu.edu/cgi/viewcontent.cgi?article=1086&context=cate

Breger, Benjamin S., Theodore S. Eisenman, Madison E. Kremer, Lara A. Roman, Deborah G. Martin, John Rogan. 2019. “Urban Tree Survival and Stewardship in a State-Managed Planting Initiative: A Case Study in Holyoke, Massachusetts.” *Urban Forestry & Urban Greening* 43. <https://doi.org/10.1016/j.ufug.2019.126382>

City of Oklahoma City. “GreenOKC: Environmental and Natural Resources.” 2015. Accessed February 2024. <https://planokc.org/greenokc/>.

Coder, Kim D. 2000. Tree Root Growth Requirements. University of Georgia Warnell School of Forest Resources Extension. <https://arborcaresolutions.com.au/treerootgrowth.pdf>

Conway, Stanley M. and Elizabeth Bang. 2014. “Willing Partners? Residential Support for Municipal Urban Policies.” *Urban Forestry and Urban Greening* 13: 234-243. <http://dx.doi.org/10.1016/j.ufug.2014.02.003>

City of Oklahoma City. 2009. Putting Down Roots. By Aubrey Hammontree. <https://www.okc.gov/home/showpublisheddocument/3582/635980455431100000>

Craul, Phillip J. 1999. “Tree Planting Techniques.” in *Urban Soils: Applications and Practices*. John Wiley and Sons Inc.

Deming, M. Elen, and Paul Littleton. “Ann Arbor Municipal Center.” *Landscape Performance Series*. Landscape Architecture Foundation, 2013. <https://doi.org/10.31353/cs0460>

Ely, Martin. 2013. “Planning With Trees in Mind.” *Australian Planner* 46, no. 3: 16-19. <https://doi.org/10.1080/07293682.2009.10753404>.

Hauer, Richard, Robert W. Miller, Daniel M. Ouimet. 1994. “Street Tree Decline and Construction Damage,” *Journal of Arboriculture* 20 (2): 94-97. <https://doi.org/10.48044/jauf.1994.017>.

Kansas Forest Service. 2018. “Preferred Trees for Northeast Kansas.” Kansas Forest Service. <https://www.kansasforests.org/resources/recommendedtreesandshrubs.html>.

Kansas Forest Service. 2023. “The Right Tree for my Soil”. Kansas Forest Service. https://www.kansasforests.org/conservation_trees/soil.html.

Kondo, Michelle, Bernadette Hohl, SeungHoon Han, and Charles Branas. 2016. “Effects of Greening and Community Reuse of Vacant Lots on Crime.” *Urban Studies* 53, no 15: 3279–3295. <https://www.jstor.org/stable/26151282>.

Kuo, Frances E. 2003. “The Role of Arboriculture in a Healthy Social Ecology.” *Journal of Arboriculture* 29 (3): 148-155. <https://nfs.unl.edu/documents/communityforestry/Kuoroleofarboricultureinhealthysociety.pdf>

Lines, Emily R., David A. Coomes, Drew W. Purves. 2010. “Influences of Forest Structure, Climate and Species Composition on Tree Mortality Across the Eastern U.S.” *PlosOne* 5 (10): 1-12. <https://doi.org/10.1371/journal.pone.0013212>.

Lu, Jacqueline W.T., Erika S. Svendsen, Lindsay K. Campbell, Jennifer Greenfield, Jessie Braden, Kristen L. King, and Nancy Falxa-Raymond. 2010. “Biological, Social, and Urban Design Factors Affecting Young Street Tree Mortality in New York City.” *Cities and the Environment*, 3: 5, 1-13. <https://digitalcommons.lmu.edu/cate/vol3/iss1/5>

Manhattan : City of Manhattan, Kansas. “Manhattan Urban Area Comprehensive Plan.” March 2015. Accessed February 2024. <https://cityofmhk.com/DocumentCenter/View/32591/Full-Manhattan-Urban-Area-Comprehensive-Plan---2015-2023-Amendment?bidId=>

McPherson, Gregory E. 2001. “Sacramento’s Parking Lot Shading Ordinance: Environmental and Economic Costs of Compliance.” *Landscape and Urban Planning* 57: 105-123. [https://doi.org/10.1016/S0169-2046\(01\)00196-7](https://doi.org/10.1016/S0169-2046(01)00196-7)

References

Milosevic, Dragan D., Ivana V. Bajsanski, and Stevan M Savic. 2017. "Influence of Changing Trees' Locations on Thermal Comfort on Street Parking Lot and Footways." *Urban Forestry and Greening* 23: 113-124. <http://dx.doi.org/10.1016/j.ufug.2017.03.011>.

Nan, Xinge, Hai Yan, Huaizhen Zhu, Qian Han, Renwu Wu, and Zhiyi Bao. 2022. "Assessing the Thermal Environments of Parking Lots in Relation to Their Shade Design Characteristics." *Sustainable Cities and Society* 83 (August): 1-16. <https://doi.org/10.1016/j.scs.2022.103931>.

Nowak, David J., Joe R. McBride, and Russell A. Beatty. 1990. "Newly Planted Street Tree Growth and Mortality." *Journal of Arboriculture* 16 (5): 124-129. <http://dx.doi.org/10.48044/jauf.1990.032>.

Petri, Aaron C., Andrew K. Koesner, Sarah T. Lovell, and Dewayne Ingram. 2016. "How Green Are Trees? - Using Life Cycle Assessment Methods to Assess Net Environmental Benefits." *Journal of Environmental Horticulture* 34, no. 4: 101-110. <https://doi.org/10.24266/0738-2898-34.4.101>.

Pincetl, Stephanie, et. al. 2013. "Urban Tree Planting Programs, Function or Fashion? Los Angeles Planting Campaigns." *GeoJournal* 78, no.3: 475-493. <https://www.jstor.org/stable/42002524>.

"Riley County Community Gis Viewer." Riley County Community GIS Website, July 5, 2017. <https://gis.rileycountyks.gov/>.

Robinson, Connie. 2006. "Trees and Shrubs for Difficult Sites." Kansas State University. <https://www.kansasforests.org/resources/recommendedtreesandshrubs.html>.

A. Roman, Lara A., John J. Battles, and Joe R. McBride. 2014. "Determinants of Establishment Survival for Residential Trees in Sacramento County, CA." *Landscape and Urban Planning* 129: 22-31. <http://dx.doi.org/10.1016/j.landurbplan.2014.05.004>.

B. Roman, Lara A., John J. Battles, and Joe R. McBride. 2014. "The Balance of Planting and Mortality in a Street Tree Population," *Urban Ecosystems* 17: 387-404. <https://doi.org/10.1007/s11252-013-0320-5>.

Smith, Ian A., Victoria K. Dearborn, and Lucy R. Hutyra. 2019. "Live Fast, Die Young: Accelerated Growth, Mortality, and Turnover in Trees." *Plos One* 14, no.5. <https://doi.org/10.1371/journal.pone.0215846>.

Steenberg, James W.N., Andrew A. Millward, David J. Nowak and Pamela J. Robinson. 2017. "A Conceptual Framework of Urban Forest Ecosystem Vulnerability." *Environmental Reviews* 25, no. 15: 115-126. <https://www.jstor.org/stable/10.2307/90001424>.

Urban, James. 2007. "Alternatives to Structural Soil for Urban Trees and Rain Water." Paper presented at Designing With Nature: The Art of Balance – American Society of Landscape Architects Annual Meeting, Annapolis, Maryland, October 2007. <https://static1.squarespace.com/static/52ec31b2e4b04eb0bbd9c075/t/57cee6a5e58c6267c2301e94/1473177272167/Urban+-+Alternatives+to+Structural+Soil+-+2001.pdf>

Urban, James. Up by Roots: Healthy Soils and Trees in the Built Environment. International Society of Arboriculture, 2008.

Watson, Gary W., Angela M. Hewitt, Meliss Custic, and Marvin Lo. 2014. "The Management of Tree Root Systems in Urban and Suburban Settings II: A Review of Strategies to Mitigate Human Impacts." *Arboriculture and Urban Forestry* 40, no. 5: 249-271. <https://doi.org/10.48044/jauf.2014.025>

Watt, Fiona, Jennifer Greenfield, and Jacqueline Lu. "New York City's Young Street Tree Mortality Study." New York City: City of New York Parks and Recreation, 2010. Accessed November 2023. https://www.nycgovparks.org/sub_your_park/trees_greenstreets/images/how_to_assess_your_citys_st_survival_10-6-2010.pdf

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Riley County [KS] IT/GIS Services. 2013. "Riley County Color Aerial Imagery." Acquired by data request. CityofMHK geodatabase, Mr. SID image data format, 0.33 foot resolution.

Figure References

Figure 3.6: Saunders, Gabrielle. (2024) Tree canopy coverage diagrams for Site Two in 2012 and 2022. Adobe Illustrator and GIS Imagery retrieved from:

Riley County [KS] IT/GIS Services. 2013. "Riley County Color Aerial Imagery." Acquired by data request. CityofMHK geodatabase, Mr. SID image data format, 0.33 foot resolution.

Figure 3.7: Saunders, Gabrielle. (2024) Site Assessment Selection. Adobe Illustrator and Google Earth (2023).

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Figure 4.2: Trees of Project 180 by DeepRoot, 2014. Retrieved from <https://www.flickr.com/photos/deeproot/>. Used under Creative Commons Attribution-NonCommercial-ShareAlike 2.0 Generic license

Figure 4.3: Cover Page of Putting Down Roots. City of Oklahoma City, 2009. Retrieved from <https://www.okc.gov/home/showpublisheddocument/3582/635980455431100000>.

Figure 4.4: Page in Putting Down Roots. City of Oklahoma City, 2009. Retrieved from <https://www.okc.gov/home/showpublisheddocument/3582/635980455431100000>.

Figure 4.5: Streeterly in Bethesda by Joe Flood, 2020. Retrieved from <https://www.flickr.com/photos/joeflood/50046409473> . Used under Creative Commons Attribution-NonCommercial-ShareAlike 2.0 Generic license.

Figure References

Figure 4.6: Graphics from "Bethesda DOWtown Plan." Bethesda: The Maryland-National Capital Park and Planning Commission, October 2020. Accessed February 2024. https://montgomeryplanning.org/wp-content/uploads/2020/10/Approved-2020-Bethesda-Streetscape-Standards_FINAL100820.pdf

Figure 4.7: 20150917-OSEC-LSC-0567 by U.S. Department of Agriculture, 2015. Retrieved from <https://www.flickr.com/photos/usdagov/21417978008> . Used under Creative Commons Attribution-NonCommercial-ShareAlike 2.0 Generic license.

Figure 4.8 : Watt, Fiona, Jennifer Greenfield, and Jacqueline Lu. "New York City's Young Street Tree Mortality Study." New York City: City of New York Parks and Recreation, 2010. Accessed November 2023. https://www.nycgovparks.org/sub_your_park/trees_greenstreets/images/how_to_assess_your_citys_st_survival_10-6-2010.pdf

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Figure 4.38: Smith, Zachary. Planting a young bare-root fruit tree. How to Plant Bare Root Fruit Trees the Right Way. The Plant Dude, January 27, 2022. <https://touchtrees.com/how-to-plant-bare-root-fruit-trees/>.

Figure 4.39: Balled & Burlapped Trees 01 by JoLynne Martinez, 2019. Retrieved from <https://www.flickr.com/photos/inannabintali/47682868282> . Used under Creative Commons Attribution-NonCommercial-ShareAlike 2.0 Generic license.

Figure 4.40: Cue, Kathleen. Bad mulching around trees. Mulch Volcanoes: A Harmful Practice for Trees. University of Nebraska-Lincoln. Accessed April 1, 2024. <https://extension.unl.edu/statewide/dodge/mulch-volcanoes-a-harmful-practice-for-trees/>.

Figure 4.41: NACTO. Pervious pavement in a parking lot. Urban Street Design Guide. Island Press. Accessed April 1, 2024. <https://nacto.org/publication/urban-street-design-guide/street-design-elements/stormwater-management/pervious-pavement/>.

Figure 4.42: Urban, James. Root path detail. The Evolution of Tree Soil Under Pavement. Accessed April 1, 2024. https://static1.squarespace.com/static/52ec31b2e4b04eb0bbd9c075/t/550b0d81e4b09c648ec29b2a/1426787713143/Evolution+of+soil+under+pavement_reduced+file+size.pdf.

Figure 4.43: Skabelund, Lee. (2017). Newly planted honeylocust trees in Silva Cells at Union Plaza in Lincoln, Nebraska. Photograph. Used with permission.

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Figure 4.46: Wilson, Brent. Methods for staking a tree. How to Stake a Newly Planted Tree and How Long to Leave It Staked. Wilson Bros Gardens, August 18, 2017. <https://www.wilsonbrosgardens.com/staking-a-new-tree.html>.

Figure 4.47: Necessary places to prune a young tree. Pruning Young Trees. Bob's Market and Greenhouses Inc., March 5, 2020. <https://www.bobsmarket.com/blog/pruning-young-trees>.

Figure 4.48: Tree Pittsburgh. (2023). “Tree Tenders” volunteering as part of the “Tree Pittsburgh” initiative in Pittsburgh, Pennsylvania. Tree Tenders Volunteer Program. Retrieved April 26, 2024, from <https://www.treepittsburgh.org/tree-tenders-volunteer-program/>.

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Riley County [KS] IT/GIS Services. 2013. "Riley County Color Aerial Imagery." Acquired by data request. CityofMHK geodatabase, Mr. SID image data format, 0.33 foot resolution.

Figure 5.5: Saunders, Gabrielle. (2024) Diagram of impervious surface coverage in Site 11. Adobe Illustrator and GIS Imagery retrieved from:

Riley County [KS] IT/GIS Services. 2013. "Riley County Color Aerial Imagery." Acquired by data request. CityofMHK geodatabase, Mr. SID image data format, 0.33 foot resolution.

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Riley County [KS] IT/GIS Services. 2013. "Riley County Color Aerial Imagery." Acquired by data request. CityofMHK geodatabase, Mr. SID image data format, 0.33 foot resolution.

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Riley County [KS] IT/GIS Services. 2013. "Riley County Color Aerial Imagery." Acquired by data request. CityofMHK geodatabase, Mr. SID image data format, 0.33 foot resolution.

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Riley County [KS] IT/GIS Services. 2013. "Riley County Color Aerial Imagery." Acquired by data request. CityofMHK geodatabase, Mr. SID image data format, 0.33 foot resolution.

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Figure 5.15: Crabapple tree in bloom by Ali Eminov, 2014. Retrieved from <https://www.flickr.com/photos/aliarda/14117252875>. Used under Creative Commons Attribution-NonCommercial-ShareAlike 2.0 Generic license.

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Riley County [KS] IT/GIS Services. 2013. "Riley County Color Aerial Imagery." Acquired by data request. CityofMHK geodatabase, Mr. SID image data format, 0.33 foot resolution.

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Figure 5.28: Bur Oak – Wind Cave National Park by National Parks Gallery, 2010. Retrieved from <https://timelessmoon.getarchive.net/media/bur-oak-9297fe>. Used under Creative Commons Attribution-NonCommercial-ShareAlike 2.0 Generic license.

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Riley County [KS] IT/GIS Services. 2013. "Riley County Color Aerial Imagery." Acquired by data request. CityofMHK geodatabase, Mr. SID image data format, 0.33 foot resolution.

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Riley County [KS] IT/GIS Services. 2013. "Riley County Color Aerial Imagery." Acquired by data request. CityofMHK geodatabase, Mr. SID image data format, 0.33 foot resolution.

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Riley County [KS] IT/GIS Services. 2013. "Riley County Color Aerial Imagery." Acquired by data request. CityofMHK geodatabase, Mr. SID image data format, 0.33 foot resolution.

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Riley County [KS] IT/GIS Services. 2013. "Riley County Color Aerial Imagery." Acquired by data request. CityofMHK geodatabase, Mr. SID image data format, 0.33 foot resolution.

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Figure 5.43: Quercus rubra by Matthieu Sontag, 2007. Retrieved from https://commons.wikimedia.org/wiki/File:Quercus_rubra.jpg. Used under Creative Commons Attribution-NonCommercial-ShareAlike 2.0 Generic license.

Figure 5.44: Pin Oak Tree by F.D. Richards, 2012. Retrieved from <https://www.flickr.com/photos/50697352@N00/8097365270>. Used under Creative Commons Attribution-NonCommercial-ShareAlike 2.0 Generic license.

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Figure 5.46: Saunders, Gabrielle. (2024) Alternative proposal located on Site 12. Adobe Illustrator, Adobe Photoshop and GIS Imagery retrieved from:

Riley County [KS] IT/GIS Services. 2013. "Riley County Color Aerial Imagery." Acquired by data request. CityofMHK geodatabase, Mr. SID image data format, 0.33 foot resolution.

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Figure 5.53: Sunburst Honey Locust leafing out in spring along Scotsmore Way in the Chantilly Highlands section of Oak Hill, Fairfax County, Virginia by Famartin, 2020. Retrieved from https://commons.wikimedia.org/wiki/File:2020-05-04_13_25_08_Sunburst_Honey_Locust_leafing_out_in_spring_along_Scotsmore_Way_in_the_Chantilly_Highlands_section_of_Oak_Hill,_Fairfax_County,_Virginia.jpg. Used under Creative Commons Attribution-NonCommercial-ShareAlike 2.0 Generic license.

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Figure 5.55: Quercus bicolor (swamp white oak) 1 by James St. John, 2021. Retrieved from <https://www.flickr.com/photos/jsigeology/51279546517>. Used under Creative Commons Attribution-NonCommercial-ShareAlike 2.0 Generic license.

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Appendix 1: Site Assessment Table

Site 1

	Species	Height (ft.)	Canopy Width (ft.)	Trunks Wounds or Signs of Suckers/ Shoots	Unnatural Lean
1	Celtis occidentalis	40-50 Feet	40-50 Feet	No	No
2	Juglans nigra	30-40 Feet	10-20 Feet	No	Yes
3	Acer rubrum	20-30 Feet	10-20 Feet	Yes	Yes
4	Acer rubrum	0-10 Feet	0-10 Feet	Yes	No
5	Acer rubrum	0-10 Feet	0-10 Feet	No	No
6	Acer rubrum	0-10 Feet	0-10 Feet	No	No
7	Fraxinus americana	40-50 Feet	30-40 Feet	No	No
8	Malus	0-10 Feet	0-10 Feet	Yes	No
9	Acer rubrum	50-60 Feet	30-40 Feet	Yes	No
10	Fraxinus americana	30-40 Feet	10-20 Feet	No	No
11	Fraxinus americana	30-40 Feet	10-20 Feet	Yes	No
12	Magnolia X soulangeana	10-20 Feet	10-20 Feet	Yes	No
13	Celtis occidentalis	50-60 Feet	40-50 Feet	No	No

	Guard, wire, or grate	Water pooling in tree pit	Tree pit type	Tree pit size	Tree distance from curb
1	No	No	Median	10 Ft.	6.5 Ft.
2	No	No	Median	10 Ft.	6 Ft.
3	No	No	Median	10 Ft.	6 Ft.
4	No	No	Median	7 Ft.	3 Ft.
5	No	No	Median	7 Ft.	3 Ft.
6	No	No	Median	7 Ft.	3 Ft.
7	No	No	Median	7 Ft.	3 Ft.
8	No	No	Bed	10 Ft. X 36 Ft.	10 Ft.
9	No	Yes	Median	8 Ft.	2 Ft.
10	No	No	Median	8 Ft.	3 Ft.
11	No	No	Median	8 Ft.	2 Ft.
12	No	No	Median	8 Ft. W	2 Ft.
13	No	No	Median	12 Ft.	5

Appendix 1: Site Assessment Table

Site 1

	Tree Grate	Curb Condition	Sidewalk Condition	Proximity to Built Structure	# Adjacent Building stories
1	No	Fair	Fair	10-20 Feet	2
2	No	Fair	Poor	0-10 Feet	2
3	No	Fair	Poor	0-10 Feet	2
4	No	Fair	Good	0-10 Feet	4
5	No	Good	Good	0-10 Feet	4
6	No	Fair	Good	10-20 Feet	4
7	No	Fair	Good	10-20 Feet	4
8	No	Good	Good	0-10 Feet	4
9	No	Good	Good	0-10 Feet	4
10	No	Good	Good	0-10 Feet	4
11	No	Good	Good	0-10 Feet	4
12	No	Good	Good	0-10 Feet	4
13	No	Good	Poor	10-20 Feet	2

	Adjacent Sidewalk Width (ft.)	Stakes and/or wiring	Pit paved to tree trunk?	Mulch in tree pit	Gravel in tree pit
1	4	No	Yes	No	No
2	5	No	No	No	No
3	5	No	No	No	No
4	6	No	No	No	No
5	6	No	No	No	No
6	6	No	No	No	No
7	6	No	No	No	No
8	5	No	No	No	Yes
9	5	No	No	No	No
10	5	No	No	No	No
11	5	No	No	No	No
12	5	No	No	No	No
13	5	No	Yes	No	No

Appendix 1: Site Assessment Table

Site 1

	Weeds/Debris	Evidence of Pruning	Lights in/ around tree	Other concerns/notes
1	No	Yes	No	Sidewalk cracked and lifted, heavily pruned, broken branches
2	No	Yes	No	Circling roots
3	No	Yes	No	Suckers and trunk wounds, heavy pruning
4	No	No	No	
5	No	No	No	
6	No	No	No	
7	No	Yes	No	Interfering with adjacent building, encroaching on balconies... dog waste can placed 1.5 Ft. away from trunk.
8	Yes - weeds	No	No	Shoots
9	Yes - debris	Yes	No	Lingering snowmelt/mud, garbage surrounding, major pruning
10	No	Yes	No	Severe pruning
11	No	Yes	No	Severe pruning, missing bark and recent wounds
12	Yes - debris	No	No	Shoots
13	No	Yes	No	Circling roots, severe pruning

Site 2

	Species	Height (ft.)	Canopy Width (ft.)	Trunks Wounds or Signs of Suckers/ Shoots	Unnatural Lean
1	Gleditsia triacanthos	40-50 Feet	30-40 Feet	No	No
2	Gleditsia triacanthos	30-40 Feet	30-40 Feet	Yes	No
3	Gleditsia triacanthos	40-50 Feet	30-40 Feet	Yes	No
4	Liquidambar styraciflua	20-30 Feet	30-40 Feet	Yes	No
5	Acer rubrum	30-40 Feet	20-30 Feet	Yes	No
6	Fraxinus americana	30-40 Feet	30-40 Feet	No	No
7	Quercus palustris	30-40 Feet	40-50 Feet	Yes	No
8	Quercus rubra	30-40 Feet	30-40 Feet	No	No
9	Quercus rubra	30-40 Feet	30-40 Feet	No	No
10	Quercus rubra	20-30 Feet	30-40 Feet	No	No
11	Quercus rubra	40-50 Feet	40-50 Feet	Yes	No
12	Ulmus americana	30-40 Feet	30-40 Feet	Yes	No
13	Fraxinus americana	30-40 Feet	20-30 Feet	No	Yes
14	Acer rubrum	10-20 Feet	0-10 Feet	No	No
15	Fraxinus americana	20-30 Feet	20-30 Feet	No	No
16	Cercis canadensis	20-30 Feet	10-20 Feet	Yes	No
17	Cercis canadensis	10-20 Feet	10-20 Feet	Yes	No

Appendix 1: Site Assessment Table

Site 2

	Guard, wire girdling	Water pooling in tree pit	Tree pit type	Tree pit size	Tree distance from curb
1	No	No	Median	8 Ft.	4 Ft.
2	No	No	Median	8 Ft.	3 Ft.
3	No	Yes	Median	8 Ft.	3 Ft.
4	No	No	Median	8 Ft.	4 Ft.
5	No	No	Median	8 Ft.	3 Ft.
6	No	No	Median	8 Ft.	3 Ft.
7	No	No	Median	8 Ft.	3 Ft.
8	No	No	Median	8 Ft.	3 Ft.
9	No	No	Median	9 Ft.	4 Ft.
10	No	No	Median	8 Ft.	4 Ft.
11	No	No	Bed	12 Ft. X 8 Ft.	0
12	No	No	Median	8 Ft. W	3 Ft.
13	No	No	Median	8 Ft.	5 Ft.
14	No	No	Median	8 Ft.	5 Ft.
15	No	No	Median	8 Ft.	2 Ft.
16	No	No	Median	8 Ft.	5 Ft.
17	No	No	Median	8 Ft.	3 Ft.

Site 2

	Tree Grate	Curb Condition	Sidewalk Condition	Proximity to Built Structure	# Adjacent Building stories
1	No	Fair	Good	10-20 Feet	3
2	No	Good	Good	10-20 Feet	3
3	No	Poor	Good	0-10 Feet	3
4	No	Fair	Fair	10-20 Feet	3
5	No	Good	Fair	10-20 Feet	3
6	No	Poor	Fair	10-20 Feet	3
7	No	Good	Fair	10-20 Feet	2
8	No	Good	Poor	10-20 Feet	2
9	No	Good	Fair	10-20 Feet	2
10	No	Fair	Fair	10-20 Feet	2
11	No	Poor	Fair	10-20 Feet	2
12	No	Poor	Good	20-30 Feet	3
13	No	Fair	Good	20-30 Feet	3
14	No	Good	Good	20-30 Feet	2
15	No	Good	Good	10-20 Feet	3
16	No	Good	Good	10-20 Feet	3
17	No	Good	Good	10-20 Feet	3

Appendix 1: Site Assessment Table

Site 2

	Adjacent Sidewalk Width	Stakes and/or wiring	Pit paved to tree trunk?	Mulch in tree pit	Gravel in tree pit
1	5	No	Yes	No	No
2	5	No	No	No	No
3	5	No	Yes	No	No
4	5	No	No	No	No
5	6	No	Yes	No	No
6	6	No	Yes	No	No
7	5	No	No	No	No
8	6	No	Yes	No	No
9	6	No	No	No	No
10	6	No	Yes	No	No
11	6	No	Yes	No	No
12	6	No	No	No	No
13	6	No	No	No	No
14	6	No	No	No	No
15	6	No	No	No	No
16	6	No	No	No	No
17	6	No	No	No	No

Site 2

	Weeds/Debris	Evidence of Pruning	Lights in/ around tree	Other concerns/notes
1	No	Yes	No	Roots and sidewalk interfering with each other, severe pruning
2	No	Yes	No	Suckers
3	Yes - weeds	Yes	No	Trunk is split, rootball raised aboveground, invasive vine crawling up
4	No	No	No	Suckers
5	Yes - debris	Yes	No	Trunk wounds and suckers, obstructing concrete.
6	No	Yes	No	
7	Yes - debris	No	No	Suckers
8	No	No	No	
9	No	No	No	
10	No	Yes	No	Circling roots, planted too closely to other trees, encroaching on concrete
11	No	No	No	Weeds/suckers growing from base of trunk.
12	No	No	No	Some suckers, circling roots
13	Yes - debris	Yes	No	Severe pruning, 30 degree angle, garbage in tree pit
14	No	Yes	No	Pruning, major branch
15	No	No	No	
16	No	Yes	No	Understory plantings in tree pit
17	No	Yes	No	Peeling bark, major pruning

Appendix 1: Site Assessment Table

Site 3

	Species	Height (ft.)	Canopy Width (ft.)	Trunks Wounds or Signs of Suckers/ Shoots	Unnatural Lean
1	Ulmus pumila	40-50 Feet	20-30 Feet	Yes	No
2	Acer saccharinum	40-50 Feet	50-60 Feet	Yes	No
3	Quercus rubra	20-30 Feet	20-30 Feet	No	No
4	Fraxinus americana	30-40 Feet	30-40 Feet	No	No
5	Cercis canadensis	0-10 Feet	0-10 Feet	No	No
6	Quercus macrocarpa	20-30 Feet	20-30 Feet	No	No
7	Pyrus calleryana	20-30 Feet	10-20 Feet	No	No
8	Fraxinus pennsylvanica	30-40 Feet	30-40 Feet	Yes	No
9	Quercus rubra	20-30 Feet	10-20 Feet	Yes	No
10	Gleditsia triacanthos	30-40 Feet	30-40 Feet	Yes	No
11	Pyrus calleryana	20-30 Feet	20-30 Feet	No	No
12	Acer rubrum	10-20 Feet	20-30 Feet	No	No
13	Ulmus americana	40-50 Feet	30-40 Feet	Yes	Yes
14	Cercis canadensis	10-20 Feet	0-10 Feet	Yes	No
15	Gladitsia triacanthos	20-30 Feet	20-30 Feet	No	No
16	Gladitsia triacanthos	40-50 Feet	50-60 Feet	No	No

	Species	Height (ft.)	Canopy Width (ft.)	Trunks Wounds or Signs of Suckers/ Shoots	Unnatural Lean
17	Acer saccharinum	30-40 Feet	30-40 Feet	Yes	No
18	Cercis canadensis	0-10 Feet	0-10 Feet	Yes	No
19	Maclura pomifera	10-20 Feet	0-10 Feet	No	No
20	Celtis occidentalis	50-60 Feet	50-60 Feet	Yes	No
21	Quercus rubrum	0-10 Feet	0-10 Feet	No	No
22	Acer saccharum	30-40 Feet	20-30 Feet	Yes	No
23	Acer saccharinum	40-50 Feet	30-40 Feet	Yes	No

Appendix 1: Site Assessment Table

Site 3

	Guard, wire girdling	Water pooling in tree pit	Tree pit type	Tree pit size	Tree distance from curb
1	No	No	Lawn	N/A	4 Ft.
2	No	No	Lawn	N/A	3 Ft.
3	No	No	Bed	20 Ft. X 6 Ft.	3 Ft.
4	No	No	Lawn	15 Ft. X 30 Ft.	3 Ft.
5	No	No	Lawn	N/A	6 Ft.
6	No	No	Median	8 Ft. W	5 Ft.
7	No	No	Median	8 Ft. W	4 Ft.
8	No	No	Median	8 Ft. W	4 Ft.
9	No	No	Median	8 Ft. W	3 Ft.
10	No	No	Median	8 Ft. W	4 Ft.
11	No	No	Lawn	N/A	5 Ft.
12	No	No	Lawn	N/A	6 Ft.
13	No	No	Lawn	N/A	10 Ft.
14	No	No	Lawn	N/A	8 Ft. W
15	No	No	Lawn	N/A	5 Ft.
16	No	No	Lawn	N/A	5 Ft.
17	No	No	Median	8 Ft. W	4 Ft.

	Guard, wire girdling	Water pooling in tree pit	Tree pit type	Tree pit size	Tree distance from curb
18	No	No	Median	8 Ft. W	4 Ft.
19	No	No	Median	8 Ft.	4 Ft.
20	No	No	Median	8 Ft. W	3 Ft.
21	No	No	Median	8 Ft. W	5 Ft.
22	No	No	Median	8 Ft. W	3 Ft.
23	No	No	Lawn	N/A	13 Ft.

Appendix 1: Site Assessment Table

Site 3

	Tree Grate	Curb Condition	Sidewalk Condition	Proximity to Built Structure	# Adjacent Building stories
1	No	Fair	Good	N/A	N/A
2	No	Poor	Good	50-60 Feet	2
3	No	Fair	Good	10-20 Feet	2
4	No	Fair	Good	0-10 Feet	2
5	No	Fair	Good	0-10 Feet	2
6	No	Fair	Good	10-20 Feet	2
7	No	Fair	Good	10-20 Feet	2
8	No	Fair	Fair	10-20 Feet	2
9	No	Good	Good	10-20 Feet	1
10	No	Good	Fair	10-20 Feet	1
11	No	Fair	Good	0-10 Feet	1
12	No	Good	Good	0-10 Feet	1
13	No	Good	Good	0-10 Feet	1
14	No	Good	Good	10-20 Feet	1
15	No	Good	Good	30-40 Feet	3
16	No	Good	Good	10-20 Feet	3
17	No	Fair	Good	10-20 Feet	3

	Tree Grate	Curb Condition	Sidewalk Condition	Proximity to Built Structure	# Adjacent Building stories
18	No	Good	Fair	10-20 Feet	3
19	No	Fair	Fair	10-20 Feet	3
20	No	Fair	Good	10-20 Feet	1
21	No	Fair	Good	10-20 Feet	3
22	No	Poor	Good	20-30 Feet	3
23	No	Good	Good	0-10 Feet	3

Appendix 1: Site Assessment Table

Site 3

	Adjacent Sidewalk Width	Stakes and/or wiring	Pit paved to tree trunk?	Mulch in tree pit	Gravel in tree pit
1	N/A	No	No	No	No
2	N/A	No	No	No	No
3	N/A	No	No	No	No
4	N/A	No	No	No	No
5	N/A	No	No	No	No
6	6	No	No	No	No
7	6	No	No	No	No
8	6	No	No	No	No
9	6	No	No	No	No
10	6	No	No	No	No
11	6	No	No	No	No
12	N/A	No	No	No	No
13	N/A	No	No	No	No
14	N/A	No	No	No	No
15	N/A	No	No	No	No
16	N/A	No	No	No	No
17	6	No	Yes	No	No

	Adjacent Sidewalk Width	Stakes and/or wiring	Pit paved to tree trunk?	Mulch in tree pit	Gravel in tree pit
18	6	No	No	No	No
19	6	No	No	No	No
20	6	No	Yes	No	No
21	6	No	No	No	No
22	6	No	No	No	No
23	6	No	Yes	No	No

Appendix 1: Site Assessment Table

Site 3

	Weeds/Debris	Evidence of Pruning	Lights in/ around tree	Other concerns/notes
1	No	Yes	No	Basically dead, peeling bark/ discoloration
2	Yes - weeds	No	No	Invasive vine overtaking, very close to underground utilities, interference with power lines, broken branches
3	Yes - debris	No	No	
4	No	Yes	No	Interfering with adjacent building
5	No	No	No	
6	No	No	No	Planted too close to adjacent tree, canopies are interfering
7	No	Yes	No	Roots are interfering with curb
8	No	Yes	Yes	Suckers/peeling bark, roots growing into curb
9	No	No	No	Small suckers at base of tree
10	No	Yes	No	Major branch pruned over road
11	No	No	No	
12	Yes - debris	No	No	
13	No	Yes	No	Lots of suckers, peeling bark, discoloration, leaning away from building, has been pruned heavily due to building/street interference, dead/dangling branches
14	Yes - weeds	Yes	No	Trunk wounds, suckers/shoots, invasive vine taking over.

	Weeds/Debris	Evidence of Pruning	Lights in/ around tree	Other concerns/notes
15	No	Yes	No	
16	No	Yes	No	
17	No	Yes	No	
18	No	Yes	No	
19	No	Yes	No	Discoloration/inconsistent branches, suckers
20	Yes - weeds	Yes	No	Invasive vine, pruning branches over street
21	No	No	No	Planted too low
22	No	Yes	No	Trunk wounds, peeling bark, major pruning
23	Yes - weeds	Yes	No	Suckers, invasive vines, lots of pruning over time

Appendix 1: Site Assessment Table

Site 5

	Species	Height (ft.)	Canopy Width (ft.)	Trunks Wounds or Signs of Suckers/ Shoots	Unnatural Lean
1	Quercus rubra	10-20 Feet	20-30 Feet	Yes	No
2	Quercus rubra	40-50 Feet	40-50 Feet	Yes	No
3	Platanus occidentalis	50-60 Feet	30-40 Feet	Yes	No
4	Liquidambar styraciflua	40-50 Feet	20-30 Feet	No	No
5	Pyrus calleryana	10-20 Feet	10-20 Feet	No	No
6	Quercus rubra	30-40 Feet	20-30 Feet	Yes	No
7	Liquidambar styraciflua	40-50 Feet	40-50 Feet	Yes	No
8	Quercus rubra	20-30 Feet	20-30 Feet	Yes	No
9	Quercus rubra	40-50 Feet	20-30 Feet	Yes	No
10	Acer rubra	0-10 Feet	0-10 Feet	Yes	No
11	Quercus rubra	50-60 Feet	40-50 Feet	No	No
12	Quercus rubra	40-50 Feet	20-30 Feet	Yes	No
13	Quercus rubra	30-40 Feet	20-30 Feet	No	No
14	Acer saccharum	40-50 Feet	30-40 Feet	Yes	No
15	Quercus rubra	20-30 Feet	30-40 Feet	No	No
16	Acer rubrum	0-10 Feet	0-10 Feet	Yes	No
17	Quercus rubra	40-50 Feet	40-50 Feet	No	No

	Species	Height (ft.)	Canopy Width (ft.)	Trunks Wounds or Signs of Suckers/ Shoots	Unnatural Lean
18	Ulmus americana	50-60 Feet	50-60 Feet	Yes	No
19	Acer saccharinum	50-60 Feet	50-60 Feet	Yes	No
20	Celtis occidentalis	40-50 Feet	20-30 Feet	No	Yes
21	Juglans nigra	40-50 Feet	30-40 Feet	Yes	No

Appendix 1: Site Assessment Table

Site 5

	Guard, wire girdling	Water pooling in tree pit	Tree pit type	Tree pit size	Tree distance from curb
1	No	No	Median	7 Ft. W	4 Ft.
2	No	No	Median	6 Ft. 8 in. W	0
3	No	No	Median	7 Ft. W	1.5 Ft.
4	No	No	Median	8 Ft. W	0
5	No	No	Median	8 Ft. W	3 Ft.
6	No	No	Median	8 Ft. W	0
7	No	No	Lawn	N/A	4.5 Ft.
8	No	No	Lawn	N/A	6 Ft.
9	No	No	Lawn	N/A	4 Ft.
10	No	No	Lawn	15 Ft. W 15 Ft.	6.5 Ft.
11	No	No	Lawn	25 Ft. X 20 Ft.	12 Ft.
12	No	No	Lawn	N/A	12 Ft.
13	No	No	Lawn	N/A	12 Ft.
14	No	No	Lawn	N/A	12 Ft.
15	No	No	Lawn	N/A	10 Ft.
16	No	No	Lawn	N/A	12 Ft.
17	No	No	Lawn	N/A	10 Ft.

	Guard, wire girdling	Water pooling in tree pit	Tree pit type	Tree pit size	Tree distance from curb
18	No	No	Lawn	N/A	2 Ft.
19	No	No	Lawn	N/A	2 Ft.
20	Yes	No	Lawn	N/A	2.5 Ft.

Appendix 1: Site Assessment Table

Site 5

	Tree Grate	Curb Condition	Sidewalk Condition	Proximity to Built Structure	# Adjacent Building stories
1	No	Good	Poor	10-20 Feet	2
2	No	Good	Poor	10-20 Feet	2
3	No	Fair	Fair	10-20 Feet	2
4	No	Fair	Fair	10-20 Feet	1
5	No	Good	Good	30-40 Feet	2
6	No	Good	Good	10-20 Feet	2
7	No	Poor	Good	10-20 Feet	2
8	No	Fair	Good	10-20 Feet	2
9	No	Good	Good	20-30 Feet	2
10	No	Fair	Good	10-20 Feet	2
11	No	Good	Fair	20-30 Feet	3
12	No	Good	Good	20-30 Feet	2
13	No	Good	Good	20-30 Feet	2
14	No	Good	Good	10-20 Feet	2
15	No	Good	Fair	10-20 Feet	3
16	No	Good	Good	10-20 Feet	3
17	No	Good	Good	10-20 Feet	3

	Tree Grate	Curb Condition	Sidewalk Condition	Proximity to Built Structure	# Adjacent Building stories
18	No	Good	Fair	20-30 Feet	2
19	No	Fair	Good	0-10 Feet	3
20	No	Fair	Good	30-40 Feet	N/A
21	No	Fair	Good	10-20 Feet	2

Appendix 1: Site Assessment Table

Site 5

	Adjacent Sidewalk Width	Stakes and/or wiring	Pit paved to tree trunk?	Mulch in tree pit	Gravel in tree pit
1	6	No	Yes	No	No
2	6	No	Yes	No	No
3	6	No	Yes	No	No
4	6	No	Yes	No	No
5	6	No	No	No	No
6	6	No	No	No	No
7	N/A	No	No	No	No
8	N/A	No	No	No	No
9	N/A	No	No	No	No
10	4	No	No	No	No
11	6	No	Yes	No	No
12	6	No	Yes	No	No
13	6	No	No	No	No
14	6	No	Yes	No	No
15	6	No	No	No	No
16	6	No	No	No	No
17	6	No	No	No	No

	Adjacent Sidewalk Width	Stakes and/or wiring	Pit paved to tree trunk?	Mulch in tree pit	Gravel in tree pit
18	6	No	No	No	No
19	N/A	No	Yes	No	No
20	N/A	No	No	No	No
21	N/A	No	No	No	No

Appendix 1: Site Assessment Table

Site 5

	Weeds/Debris	Evidence of Pruning	Lights in/ around tree	Other concerns/notes
1	No	Yes	No	Peeling bark
2	No	Yes	No	Large branches removed
3	No	No	No	Branches interfering with building, healed trunk wounds
4	Yes - debris	Yes	No	
5	No	Yes	No	Circling roots, major branch damage, shoots, major pruning presence
6	No	Yes	No	Planted too high, old wounds
7	No	No	Yes	Planted too high
8	No	Yes	No	
9	Yes - weeds	Yes	No	Peeling bark/suckers, substantial pruning
10	No	Yes	No	Sun-scorched, major trunk wounds, can't tell if tree is alive or not, suckers, major pruning
11	No	No	No	Roots growing into sidewalk
12	Yes - weeds	No	No	Shoots/broken branches, invasive ivy taking over
13	Yes - debris	Yes	No	Planted low
14	Yes - debris	No	No	Garbage and branch damage
15	No	Yes	No	Pruning close to power line
16	No	No	No	Sun-scorched

	Weeds/Debris	Evidence of Pruning	Lights in/ around tree	Other concerns/notes
17	Yes - debris	Yes	No	
18	No	Yes	No	Circling roots, broken branches
19	No	Yes	No	Major trunk wounds, suckers, pruned due to interference with building
20	No	No	No	Interference with power lines
21	No	No	No	

Appendix 1: Site Assessment Table

Site 7

	Species	Height (ft.)	Canopy Width (ft.)	Trunks Wounds or Signs of Suckers/ Shoots	Unnatural Lean
1	Fraxinus americana	30-40 Feet	40-50 Feet	Yes	No
2	Ulmus parvifolia	20-30 Feet	20-30 Feet	No	No
3	Platanus occidentalis	40-50 Feet	40-50 Feet	No	No
4	Betula nigra	30-40 Feet	40-50 Feet	No	No
5	Cercis canadensis	0-10 Feet	10-20 Feet	Yes	Yes
6	Pyrus calleryana	20-30 Feet	10-20 Feet	No	No
7	Pyrus calleryana	20-30 Feet	10-20 Feet	No	No
8	Koelreuteria paniculata	20-30 Feet	20-30 Feet	No	No
9	Celtis occidentalis	40-50 Feet	20-30 Feet	No	No
10	Quercus palustris	50-60 Feet	50-60 Feet	Yes	No
11	Platanus occidentalis	50-60 Feet	40-50 Feet	Yes	No
12	Fraxinus americana	30-40 Feet	20-30 Feet	No	No
13	Quercus palustris	60-70 Feet	60-70 Feet	No	No
14	Quercus palustris	40-50 Feet	30-40 Feet	No	No
15	Platanus occidentalis	20-30 Feet	40-50 Feet	No	No
16	Quercus palustris	40-50 Feet	30-40 Feet	No	Yes
17	Liquidambar styraciflua	30-40 Feet	30-40 Feet	No	No

Site 7

	Guard, wire girdling	Water pooling in tree pit	Tree pit type	Tree pit size	Tree distance from curb
1	No	No	Median	8 Ft. W	2 Ft.
2	No	No	Median	8 Ft. X 21 Ft.	3 Ft.
3	No	No	Median	8 Ft. W	3 Ft.
4	No	No	Median	8 Ft. W	3 Ft.
5	No	No	Median	8 Ft. W	4 Ft.
6	No	No	Median	8 Ft. W	3 Ft.
7	No	No	Median	8 Ft. W	3 Ft.
8	No	No	Median	8 Ft. W	3 Ft.
9	No	No	Median	8 Ft. W	0
10	No	No	Median	8 Ft. W	0
11	No	No	Median	8 Ft. W	1 Ft.
12	No	No	Median	8 Ft. W	3 Ft.
13	No	No	Median	8 Ft. X 15 Ft.	0
14	No	No	Lawn	8 Ft. W	1 Ft.
15	No	No	Median	8 Ft. W	3 Ft.
16	No	No	Median	8 Ft. W	3 Ft.
17	No	No	Median	8 Ft. W	1 Ft.

Appendix 1: Site Assessment Table

Site 7

	Tree Grate	Curb Condition	Sidewalk Condition	Proximity to Built Structure	# Adjacent Building stories
1	No	Fair	Good	10-20 Feet	3
2	No	Fair	Good	30-40 Feet	2
3	No	Good	Fair	10-20 Feet	2
4	No	Fair	Good	10-20 Feet	3
5	No	Good	Good	10-20 Feet	1
6	No	Fair	Fair	10-20 Feet	2
7	No	Fair	Fair	10-20 Feet	2
8	No	Fair	Fair	10-20 Feet	2
9	No	Poor	Poor	20-30 Feet	1
10	No	Poor	Poor	10-20 Feet	1
11	No	Fair	Poor	0-10 Feet	3
12	No	Good	Fair	20-30 Feet	2
13	No	Poor	Poor	10-20 Feet	2
14	No	Fair	Fair	10-20 Feet	2
15	No	Good	Good	20-30 Feet	2
16	No	Fair	Good	10-20 Feet	2
17	No	Good	Good	10-20 Feet	2

Site 7

	Adjacent Sidewalk Width	Stakes and/or wiring	Pit paved to tree trunk?	Mulch in tree pit	Gravel in tree pit
1	5	No	Yes	No	No
2	5	No	No	No	No
3	5	No	Yes	No	No
4	5	No	No	No	No
5	5	No	No	No	No
6	6	No	No	No	No
7	6	No	No	No	No
8	6	No	No	No	No
9	6	No	Yes	No	No
10	6	No	Yes	No	No
11	6	No	Yes	No	No
12	6	No	No	No	No
13	6	No	Yes	No	No
14	6	No	Yes	No	No
15	6	No	No	No	No
16	6	No	No	No	No
17	6	No	Yes	No	No

Appendix 1: Site Assessment Table

Site 7

	Weeds/Debris	Evidence of Pruning	Lights in/ around tree	Other concerns/notes
1	Yes - debris	Yes	No	Discoloration and trunk/root wounds, major pruning
2	Yes - debris	Yes	No	
3	Yes - debris	No	No	Branches hanging over road
4	Yes - debris	No	No	
5	Yes - debris	Yes	No	Trunk wounds, suckers/shoots, severely pruned, in bad shape
6	No	Yes	No	
7	No	Yes	No	
8	No	No	No	
9	No	Yes	No	Major branches pruned, sidewalk/curb overtaken by roots
10	Yes - debris	No	No	Large branches hanging over sidewalk
11	No	No	No	Suckers, damaged sidewalk
12	No	No	No	Circling roots, dog toy stuck in branches
13	No	Yes	No	Sidewalk was modified to make more room for the trunk, major pruning + low-hanging branches, post placed ~3 Ft. from trunk
14	Yes - weeds	Yes	No	
15	Yes - debris	No	No	Peeling bark
16	Yes - weeds	Yes	No	
17	Yes - debris	No	No	

Site 10

	Species	Height (ft.)	Canopy Width (ft.)	Trunks Wounds or Signs of Suckers/ Shoots	Unnatural Lean
1	Quercus rubra	10-20 Feet	0-10 Feet	No	No
2	Quercus rubra	40-50 Feet	50-60 Feet	No	No
3	Celtis occidentalis	40-50 Feet	20-30 Feet	No	No
4	Quercus rubra	20-30 Feet	30-40 Feet	No	No
5	Quercus palustris	60-70 Feet	40-50 Feet	Yes	No
6	Quercus rubra	30-40 Feet	40-50 Feet	Yes	No
7	Ulmus americana	40-50 Feet	40-50 Feet	No	No
8	Fraxinus americana	30-40 Feet	20-30 Feet	Yes	No
9	Ulmus parvifolia	20-30 Feet	30-40 Feet	No	No
10	Saccharum	10-20 Feet	0-10 Feet	Yes	No
11	Acer rubrum	20-30 Feet	20-30 Feet	No	No
12	Quercus imbricaria	20-30 Feet	30-40 Feet	Yes	No
13	Acer saccharum	20-30 Feet	10-20 Feet	No	No

Appendix 1: Site Assessment Table

Site 10

	Guard, wire, or grate	Water pooling in tree pit	Tree pit type	Tree pit size	Tree distance from curb
1	No	No	Median	8 Ft. W	5 Ft.
2	No	No	Median	8 Ft. W	0
3	No	No	Median	8 Ft. W	1.5 Ft.
4	No	No	Median	8 Ft. W	3
5	No	No	Median	8 Ft. W	1 Ft.
6	No	No	Median	8 Ft. W	0
7	No	No	Median	8 Ft. W	0
8	No	No	Median	8 Ft. W	2 Ft.
9	No	No	Median	8 Ft. W	3 Ft.
10	No	No	Median	8 Ft. W	3 Ft.
11	No	No	Median	8 Ft. W	3
12	No	No	Median	8 Ft. W	3 Ft.
13	No	No	Median	8 Ft. W	3 Ft.

Site 10

	Tree Grate	Curb Condition	Sidewalk Condition	Proximity to Built Structure	# Adjacent Building stories
1	No	Good	Good	10-20 Feet	3
2	No	Poor	Good	10-20 Feet	3
3	No	Good	Fair	0-10 Feet	1
4	No	Good	Fair	0-10 Feet	2
5	No	Fair	Good	10-20 Feet	2
6	No	Poor	Fair	10-20 Feet	1
7	No	Fair	Fair	10-20 Feet	3
8	No	Good	Good	10-20 Feet	3
9	No	Poor	Good	10-20 Feet	3
10	No	Good	Poor	30-40 Feet	3
11	No	Fair	Good	20-30 Feet	2
12	No	Good	Fair	10-20 Feet	3
13	No	Fair	Good	10-20 Feet	3

Appendix 1: Site Assessment Table

Site 10

	Adjacent Sidewalk Width (ft.)	Stakes and/or wiring	Pit paved to tree trunk?	Mulch in tree pit	Gravel in tree pit
1	6	No	No	No	No
2	6	No	Yes	No	No
3	6	No	No	No	No
4	6	No	No	No	No
5	6	No	Yes	No	No
6	6	No	Yes	No	No
7	6	No	Yes	No	No
8	6	No	No	No	No
9	6	No	No	No	No
10	6	No	No	No	No
11	6	No	No	No	No
12	6	No	No	No	No
13	6	No	No	No	No

Site 10

	Weeds/Debris	Evidence of Pruning	Lights in/ around tree	Other concerns/notes
1	No	No	No	
2	No	Yes	No	Circling roots, minor pruning
3	No	Yes	No	Hanging over adjacent building's roof, pruning from a while ago
4	No	Yes	No	Pruned due to interference with building
5	No	Yes	No	Huge hole in the trunk, pruned over street
6	Yes - weeds	Yes	No	Suckers, invasive vine starting to climb, heavy pruning, root interference on the curb
7	No	Yes	No	Pruned due to interference w/ building
8	No	Yes	No	Planted too close to neighboring tree, trunk wounds, circling roots, some pruning
9	No	No	No	
10	No	No	No	Trunk wounds, dead branches. peeling bark
11	Yes - weeds	Yes	No	Circling roots
12	No	Yes	No	Suckers, pruned due to overhanging sidewalk
13	Yes - debris	Yes	No	Heavy pruning

Appendix 2: Relevant Manhattan, Kansas Development Code

Requirement	Min./Max.	Site 1 (MHK)	Site 1 (Alt.)	Site 2 (MHK)	Site 2 (Alt.)
Lot Width	60 (RH) 100 (RC) min.				
Building Height Max.					
6-17 DU (RH)	45 Ft				
18+ DU (RH)	55 Ft.				
Mid-Rise (RC)	85 Ft.				
Yard Minimums					
Front					
6-17 DU (RH)	15				
18+ DU (RH)	20				
Mid-Rise (RC)	10a				
Side					
6-17 DU (RH)	5				
18+ DU (RH)	5				
Mid-Rise (RC)	0				
Street Side					
6-17 DU (RH)	10				
18+ DU (RH)	15				
Mid-Rise (RC)	10				
Rear					
6-17 DU (RH)	20				
18+ DU (RH)	20				
Mid-Rise (RC)	0				

Appendix 2: Relevant Manhattan, Kansas Development Code

Requirement	Min./Max.	Site 1 (MHK)	Site 1 (Alt.)	Site 2 (MHK)	Site 2 (Alt.)
Building Coverage Max.					
6-17 DU (RH)	40				
18+ DU (RH)	40				
Mid-Rise (RC)	100				
Lots with Alley Access					
Parking may only be accessible from the alley, NOT from the street	yes/no				
Curb Cuts					
All	1 per lot max.				
Located to avoid removal of existing street trees	yes/no				
Street Trees					
1 overstory tree per 40 feet of street frontage	1 / 40 ft. min.				
Removed from the R.O.W. must be replaced as close to the location as practicable	yes/no				

Requirement	Min./Max.	Site 1 (MHK)	Site 1 (Alt.)	Site 2 (MHK)	Site 2 (Alt.)
Entrances					
All dwelling units must have access to a public sidewalk	yes/no				
Green Space					
Percentage of the site to be maintained as landscaped open space	15% min.				
Required Min. Parking					
MF Dwelling	1 per bedroom				
Mixed-Use (Live/Work)	1 per dwelling unit				
Mixed-Use (Mid-Rise)	.5 per bedroom				
Plant Materials					
Prohibited					
Ailanthus	yes/no				
Boxelder	yes/no				
Cottonwood	yes/no				
Elm, Siberian	yes/no				
Evergreens	yes/no				
Fruit trees	yes/no				
Maple, silver	yes/no				
Mimosa	yes/no				
Olive, Russian	yes/no				
Poplar, Lombardy	yes/no				
Weeping trees	yes/no				
Willows	yes/no				
Shrubs	yes/no				

Appendix 2: Relevant Manhattan, Kansas Development Code

Requirement	Min./Max.	Site 1 (MHK)	Site 1 (Alt.)	Site 2 (MHK)	Site 2 (Alt.)
Min. Planting Sizes and Varieties					
Overstory Trees	2.5 in. caliper				
Understory Trees	1.5 in. caliper				
Evergreen/ Conifers	6 ft. tall				
Shrubs	2 gal. container				
Ornamental Grasses	1 gal. container				
Spacing					
All plants must be sited and spaced to allow for appropriate growth to mature size	yes/no				
Landscaped Area					
All areas free of buildings, paving or other hard surfaces must be landscaped with turf grass, prairie grass, plant beds, shrubs, or trees	yes/no				

Requirement	Min./Max.	Site 1 (MHK)	Site 1 (Alt.)	Site 2 (MHK)	Site 2 (Alt.)
Mulch/ Inorganic Ground Cover					
NO synthetic turf	yes/no				
Min. Landscape Planting Requirements					
Building Foundations					
Next to and along no less than 30 percent of all building foundation lines that face or front a public street or private drive and not in a clear vision triangle area.	30% min.				
Street Trees					
Within the tree lawn of a street right-of-way and not in a clear vision triangle area.	yes/no				

Appendix 2: Relevant Manhattan, Kansas Development Code

Requirement	Min./Max.	Site 1 (MHK)	Site 1 (Alt.)	Site 2 (MHK)	Site 2 (Alt.)
One overstory tree (minimum 10' tall) for every 50' of street frontage, excluding driveways	50' min.				
Off-Street Parking Areas					
All rows of parking must be terminated with a curbed landscaped island	9'x16' min.				
Max. distance a tree can be from a parking space	70' max.				
Landscaping must be along at least 75% of the linear feet of frontage between the parking lot and the adjoining public street or private drive	75% min.				

Requirement	Min./Max.	Site 1 (MHK)	Site 1 (Alt.)	Site 2 (MHK)	Site 2 (Alt.)
All parking lot landscape islands must be landscaped with a combination of turf grass, prairie grass, plant beds, rock, wood chips, or shrubs, and trees	yes/no				
One overstory tree must be planted within each required landscape island	1 overstory tree min.				
Tree Preservation Credit					
6-12 in. caliper	3 overstory trees				
12-24 in. caliper	4 overstory trees				
24-36 in. caliper	5 overstory trees				
>36 in. caliper	6 overstory trees				

