Urban Watershed Forestry Manual

Part 3: Urban Tree Planting Guide

United States Department of Agriculture
Forest Service
Northeastern Area
State and Private Forestry

NA-TP-01-06
September 2006

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Part 3. Urban Tree Planting Guide

Third in a Three-Part Manual Series on Using Trees to Protect and Restore Urban Watersheds

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Prepared for and published by:

United States Department of Agriculture
Forest Service
Northeastern Area
State and Private Forestry
11 Campus Boulevard, Suite 200
Newtown Square, PA 19073
www.na.fs.fed.us

September 2006

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ABOUT THIS MANUAL SERIES

This is the third in a three-manual series on using trees to protect and restore urban watersheds. A brief description of each part follows.

Part 1. Methods for Increasing Forest Cover in a Watershed introduces the emerging topic of urban watershed forestry. This part also presents new methods for the watershed planner or forester, to systematically measure watershed forest cover and select the best methods for maintaining or increasing this cover by protecting, enhancing, and reforesting large parcels of primarily public land across the watershed. These methods are based on extensive review of the latest research and input from experts in a wide range of related fields.

Part 2. Conserving and Planting Trees at Development Sites presents specific ways to enable developers, engineers, or landscape architects to incorporate more trees into a development site. The proposed approach focuses on protecting existing trees, planting trees in storm water treatment practices, and planting trees in other open spaces at a development site. This part introduces conceptual designs for storm water treatment practices that utilize trees as part of the design (referred to as storm water forestry practices). These designs were developed with input from experts in storm water engineering, forestry, and a range of related fields.

Part 3. Urban Tree Planting Guide provides detailed guidance on urban tree planting that is applicable at both the development site and the watershed scales. Topics covered include site assessment, planting design, site preparation and other pre-planting considerations, and planting and maintenance techniques. An Urban Tree Selection Guide is included for use in selecting the best tree and shrub species for the planting site.

Urban watershed forestry is a new practice that draws from multiple disciplines, including forestry, hydrology, engineering, landscape architecture, mapping, planning, and soil science. Consequently, some ideas drawn from each discipline have been simplified in this manual in order to be easily understood by a diverse audience. In addition, the latest and most relevant research from each discipline has been used to support the new practice. The research summarized in this manual, however, is not intended to provide a comprehensive literature review.

This manual series draws heavily upon research and examples from the Chesapeake Bay watershed and the northeastern region of the United States. The manuals primarily apply to these regions, and may also apply in other humid regions of the country where the natural vegetative cover is predominately forest. Finally, several elements in the manuals are brand new and will require additional testing, research, and analysis. We welcome future additions to the methodology and techniques presented.

The views expressed herein are solely those of the authors and are not necessarily endorsed by the National Fish and Wildlife Foundation, U.S. Environmental Protection Agency, or the reviewers and contributors to the manual.

ACKNOWLEDGMENTS

This manual was developed by the Center for Watershed Protection (CWP) in cooperation with the USDA Forest Service, Northeastern Area State and Private Forestry. Funding for this project was provided by the USDA Forest Service through the National Fish and Wildlife Foundation, under grant number 2004-0001-001, and through the Chesapeake Bay Program Forestry Workgroup, under grant number 03-DG-11244225-163.

The preparation of the manual was greatly influenced by two design workshops held in Annapolis, MD, in winter 2004. The first workshop focused on developing conceptual designs for integrating trees and storm water treatment practices, while the second workshop developed guidelines for planting trees in specific urban locations. More than 40 local, regional, and national experts participated in the workshops, including foresters, storm water engineers, landscape architects, arborists, urban soil scientists, watershed planners, and representatives from parks, and transportation and utility companies.

The Center for Watershed Protection project team included:

- Karen Cappiella
- Tom Schueler
- Jennifer Tomlinson
- Tiffany Wright

Thanks go to Sarah Weammert and Bryan Astheimer of CWP for their assistance compiling the Urban Tree Selection Guide.

Special thanks are extended to Ryan Burdge, NFWF project administrator; and to the following staff of the USDA Forest Service: Al Todd, watershed project officer; Roderick Salguaro and Lisa D. Hoover for their assistance in compiling and reviewing the Urban Tree Database; and to Matt Arnn for developing the graphics in this manual.

Thanks go to the following reviewers of Part 3:

- Al Todd, USDA Forest Service
- James Urban, James Urban and Associates
- Sharon Schueler, City of Baltimore Department of Recreation and Parks
- Fran Spero, City of Baltimore Department of Recreation and Parks
- Phillip Rodbell, USDA Forest Service

Participants of the two design workshops are listed below:

- Matt Arnn, USDA Forest Service
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- Ted Brown, Center for Watershed Protection
- Rick Brush, Montgomery County, MD, Department of Permitting Services
- Karen Cappiella, Center for Watershed Protection

- Sally Claggett, USDA Forest Service
- Steve Cohen, KCI Technologies, Inc.
- Stewart Comstock, Maryland Department of the Environment
- Martha Corrozi, Chesapeake Bay Program
- Martin Covington, Carroll County, MD, Bureau of Resource Management
- Jennifer Curkendall, USDA Forest Service
- Doug Curtis, National Park Service, U.S. Department of the Interior
- Allen Davis, University of Maryland
- Barbara Deutsch, Casey Tree Endowment
- Mike Galvin, Maryland Department of Natural Resources
- Steve Genua, Potomac Electric Power Company (PEPCO)
- Jason Grabosky, Rutgers University
- Mark Green, City of Topeka, KS
- Guy Hager, Parks and People Foundation
- Michael Helfrich, Gamma Engineering
- Lili Herrera, Cornell University
- Brian Le Couteur, Metropolitan Washington Council of Governments
- Vicki Luther, Carroll County, MD Bureau of Resource Management
- Reggie Parrish, U.S. Environmental Protection Agency
- Rich Pouyat, USDA Forest Service
- Graham Ray, Deep Root Partners, L. P.
- Julian Ray, Deep Root Partners, L. P.
- Phillip Rodbell, USDA Forest Service
- Frank Rodgers, Parks and People Foundation
- Tom Schueler, Center for Watershed Protection
- Richard Straight, USDA Forest Service
- Anne Strang, Maryland Department of Natural Resources Forest Service
- Chris Swann, Center for Watershed Protection
- Al Todd, USDA Forest Service
- James Urban, James Urban and Associates
- Charles Wallis, Maryland Department of the Environment
- Tom Whitlow, Cornell Urban Horticulture Institute
- Tiffany Wright, Center for Watershed Protection
- Kaveh Zomorodi, Dewberry and Davis
- Roberta Zwier, AMEC Earth and Environmental

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Chapter 1. Introduction

The urban landscape can be a harsh environment for trees. A variety of pollutants, temperature extremes, hydrologic modifications, compacted soils, invasive plants, and many other factors can make it difficult to sustain healthy tree cover (Figure 1). In fact, the average life expectancy of newly planted urban trees has been reported to be 10 to 15 years, and only 7 to 10 years for urban street trees (Urban, 1999; Appleton and others, 2002). While the exact causes of urban tree mortality are difficult to pinpoint and may take years to appear, some common causes are known (Box 1). Most traditional guidance on planting trees does not adequately address these factors.

The purpose of this manual is to provide detailed guidance on how to address these urban impacts and how to improve the growing environment for trees, for anyone planning an urban tree planting project.

Figure 1. A typical urban planting site has many limiting factors.

BOX 1. COMMON CAUSES OF URBAN TREE MORTALITY

- Limited soil volume
- Poor soil quality
- Air pollution
- Construction activities
- Physical damage from mowers, vehicles, or vandals
- Damage from insects or animals
- Soil compaction from heavy foot traffic
- Soil moisture extremes
- Exposure to wind and high temperatures
- Competition from invasive plant species
- Improper planting and maintenance techniques
- Poor nursery production practices
- Conflicts with infrastructure
- Disease
- Exposure to pollutants in storm water runoff

This manual builds upon Parts 1 and 2 in this manual series (Cappiella and others 2005, 2006). Part 1 provides guidance on methods to increase forest cover in a watershed, including reforesting large areas of public turf. Many of the priority urban planting locations are subject to severe stress. Table 1 indicates some of the unique stressors that frequently affect these planting areas. Column 1 in this table indicates the corresponding page number in Part 1 or 2 of this manual series that describes planting guidelines for each location.

Table 1. Special Considerations and Site Preparation for Planting Trees in Various Urban Locations

Urban Planting Location	Special Considerations (Chapter 4, this manual)					Site Preparation (Chapter 5, this manual)		
	Inadequate Soil Volume	Storm Water Runoff	Infrastructure Conflicts	Animal Impacts	Human Impacts	Trash and Debris	Poor Soils	Invasive Species
Highway rights-of-way[1]	●	◖	●	●	◖	●	●	●
Residential lawns[1]	◖	◖	◖	◖	●	◖	◖	◖
Local streets[2]	●	●	●	◖	●	◖	●	◖
Parking lots[2]	●	●	●	◖	●	◖	●	◖
Parks[1]	◖	◖	◖	◖	●	●	◖	◖
School grounds[1]	◖	◖	◖	◖	●	●	◖	◖
Storm water dry ponds[1]	●	●	◖	◖	◖	◖	●	●
Streams and shorelines[1]	◖	◖	◖	◖	◖	●	◖	●
Utility corridors[1]	◖	◖	●	◖	◖	◖	◖	●
Vacant lots[1]	◖	◖	◖	◖	●	●	●	●

● = Very likely to be a consideration when planting trees in this location

◖ = May be a consideration, depending on location and site-specific factors

[1] See Part 1 of this manual series for more information on planting in this type of urban location.

[2] See Part 2 of this manual series for more information on planting in this type of urban location.

Guidance for conserving and planting trees in specific areas of a development site is provided in Part 2 of this manual series. Seven “storm water forestry practices” are recommended to integrate trees into the design of storm water treatment practices. As might be expected, the planting environment in these practices can be harsh. Table 2 presents the seven storm water forestry practices and indicates which of the urban planting considerations covered in this manual may apply. Other factors such as trash, invasive species, and animal impacts are likely to be more location-specific and may apply in any of these practices.

Table 2. Special Considerations for Planting Trees in Storm Water Treatment Practices

Typical Storm Water Treatment Practice	Special Considerations for Tree Planting	Related Storm Water Forestry Practices
Storm water wetland 	• Storm water runoff • Poor soils (e.g., pollutants from storm water runoff) • Inadequate soil volume (from compacted side slopes) • Human impacts (mowing)	Wooded wetland (Part 2, page 29)
Bioretention 	• Storm water runoff • Poor soils (e.g., pollutants from storm water runoff) • Infrastructure conflicts (underdrain)	Bioretention and bioinfiltration facilities (Part 2, page 35)
Dry swale 	• Storm water runoff • Poor soils (e.g., pollutants from storm water runoff) • Human impacts (mowing) • Inadequate soil volume	Alternating side slope plantings (Part 2, page 38) Tree check dams (Part 2, page 40)
Filter strip 	• Storm water runoff • Poor soils (e.g., pollutants from storm water runoff) • Human impacts (mowing)	Forested filter strip (Part 2, page 43) Multi-zone filter strip (Part 2, page 46)
Urban tree pit 	• Inadequate soil volume • Storm water runoff • Poor soils (e.g., pollutants from storm water runoff) • Infrastructure conflicts (underdrain)	Linear storm water tree pit (Part 2, page 49)

The techniques presented in this manual generally support the following design principles for urban tree planting, adapted from Urban (1999) and GFC (2001):

1. **Provide adequate soil volume to support trees at maturity.** A general guideline is to provide at least 2 cubic feet of usable soil for every 1 square foot of mature canopy (the area within the projected mature drip line of the tree). Planting areas should be designed as interconnected soil volumes so trees can share rooting space.

2. **Preserve and improve soil quality.** Limit clearing and grading to protect native soils at the site. Soil volume should be accessible to air, water, and nutrients. This is best done by separating paving from the tree's rooting area, which also allows for periodic inspection of the planting area. Soils should be amended if necessary to improve drainage and fertility.

3. **Provide adequate space for the tree to grow.** Design surrounding infrastructure to accommodate long-term growth of the tree, and space trees appropriately to allow for long-term growth and management.

4. **Select trees for diversity and site suitability.** Plant a variety of species that are tolerant of the climate and soil conditions as well as any urban impacts at the site.

5. **Protect trees from other impacts.** Develop designs that protect the tree over its entire life from pedestrian traffic, toxic runoff, browsing, high temperatures, and other urban impacts.

While this manual provides guidance on a variety of special planting and tree protection techniques, it also recognizes that each planting site is unique. It is not possible to address every possible planting scenario. Therefore, additional resources are provided for more information.

The rest of this manual is organized by the following chapters:

Chapter 2. Urban Reforestation Site Assessment – Describes how to evaluate site conditions to determine what to plant.

Chapter 3. Basic Planting Design – Outlines the basic elements of a planting plan that apply to most planting sites.

Chapter 4. Special Considerations for Urban Tree Planting – Describes additional considerations that are common to urban planting sites, for a planting plan.

Chapter 5. Site Preparation Techniques – Gives detailed methods for preparing the site for planting.

Chapter 6. Planting, Inspection, and Maintenance Techniques – Describes techniques that help ensure a healthy future for new plantings.

Chapter 2. Urban Reforestation Site Assessment

The Urban Reforestation Site Assessment (URSA) is used to collect detailed information about planting site conditions. The URSA provides a tool to help organize important data to help determine where and what to plant, and what special methods are needed to prepare the site and reduce conflicts due to existing site constraints. The purpose of an URSA is to collect data at the most promising reforestation sites in an urban watershed, in order to develop detailed planting plans. The goal is to have all the available information about an individual planting area contained in a single form.

This chapter describes the URSA in detail. For more information on methods to select, screen, and prioritize candidate planting sites across a watershed or development site, consult Part 1 (Chapter 2) and Part 2 (Chapter 2) of this manual series.

Nine major elements are evaluated at each potential reforestation site to develop an effective planting strategy:

1. *General Site Information* – information about the location, property owner, and current land use at the site.

2. *Climate* – climate data, to help select tree and shrub species

3. *Topography* – local topographic features that may present planting difficulty

4. *Vegetation* – data on current vegetative cover, to determine if removal of vegetation is necessary and to select tree and shrub species

5. *Soils* – soil characteristics, to determine if soil amendments are needed, and to select appropriate tree and shrub species

6. *Hydrology* – site drainage, to determine if the site has capacity to provide water quality treatment of storm water runoff, and to select tree and shrub species most tolerant of the prevailing soil moisture regime

7. *Potential Planting Conflicts* – available space for planting and other limiting factors, to define specific planting locations, select tree and shrub species, or identify special methods to improve the growing environment.

8. *Planting and Maintenance Logistics* – logistical factors that may influence tree survival and future maintenance needs

9. *Site Sketch* – detailed sketch of the planting site

The URSA can be customized based on the needs and interest of the field crew. Not all elements will apply to every planting scenario, and each section of the field sheet (Appendix A) may be adapted for the site.

The URSA is based on the assumption that planting potential at the candidate site is reasonably good. The URSA was developed based on several existing assessments listed in Table 3. In addition, the

URSA addresses specific urban planting conditions. One of these conditions, storm water runoff, is a factor that is frequently overlooked in urban reforestation projects.

Table 3. Resources Used in Creating the Urban Reforestation Site Assessment	
Site Assessment Resource	**Source**
Cornell Urban Horticulture Institute's Site Assessment Checklist	Recommended Urban Trees: Site Assessment and Tree Selection for Stress Tolerance (Bassuk and others, 2003)
Site Assessment and Species Selection Worksheet	Recommended Trees for Vermont Communities (Chapin, 2001)
Soil and Site Indicator Scorecards for Connecticut Community Gardeners	Soil Quality and Site Assessment Cards (NRCS, 2002)
Checklist 1: Site Selection	Planting Trees in Designed and Built Community Landscapes: Checklists for Success (Reynolds and Ossenbruggen, 1999)
Chapter 3: Site Assessment	Reclaiming Vacant Lots (Haefner and others, 2002)
Section 7: Site Evaluation, Planting and Establishment	Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest buffers (Palone and Todd, 1998)
Appendix H: Planting Considerations and Erosion-Control Fabric	Integrated Streambank Protection Guidelines (WSAHGP, 2002)

Some simple desktop preparation is required before going out in the field to conduct the URSA. Fields shaded in gray on the URSA field sheet should be filled out in the office, including the general site information, USDA plant hardiness zone, regional forest association, stream order (if applicable), local ordinance setbacks, and party responsible for maintenance. The soil chemistry section, which is optional, should be completed after conducting the URSA, or when soil sample results are received. Field crews may also wish to create a simple field map for locating sites if they are planning to evaluate multiple sites in one day.

Staffing requirements for the URSA typically include a two-person field crew with some local knowledge of native and invasive plant species and basic forestry training. Knowledge of storm water management, soils, and hydrologic principles are also helpful, as well as prior experience in tree planting. The URSA can be conducted by local agency staff, or by trained watershed volunteers. It takes approximately 2 hours to complete the field form for each acre of proposed planting area if simple testing methods are used. The time spent at each site will vary depending on the type and size of the site. Up to 6 hours are needed to work up a detailed planting plan for each site back in the office. The URSA should be conducted during the growing season to better observe the growing conditions and existing vegetation. Equipment needed for the URSA is listed in Box 2; most can be obtained from forestry suppliers.

BOX 2. EQUIPMENT NEEDED FOR THE URBAN REFORESTATION SITE ASSESSMENT

- Field forms
- Writing utensils
- Field maps (optional)
- Tape measure
- Local plant identification books
- Invasive species identification resources
- Camera
- Spray paint or flagging
- Jugs of water and a watch (optional)
- Screwdriver or soil penetrometer
- Piece of rebar
- Small sledge hammer
- Shovel
- pH test kit
- Soil test kits (optional)
- Tennis or table tennis balls
- Soil auger

With the exception of the general site information, all sections of the URSA Field Sheet (Appendix A) should be completed for the specific planting area, rather than for the entire property that contains the planting area. Instructions for completing each section of the field sheet are provided below.

General Site Information

In addition to completing the fields described below, field crews should photograph the planting area to record the site and anything of note as they complete the field sheet.

Location

Describe the site location, being as specific as possible, and using a consistent system for identifying planting sites. This may include noting the site address, nearest cross streets, GPS coordinates, page and grid of area map, subwatershed name, name of site, specific site identification, or all of these.

Property Owner

Note the name of the property owner. Contact the owner before conducting the field assessment, to obtain permission to access the site. Contact information may also be recorded here.

Current Land Use

Give a brief description of the general use or function of the site. Note if the site is currently under construction, and also list its intended future use, if known.

Climate

USDA Plant Hardiness Zone

Check the hardiness zone of the site using the USDA Plant Hardiness Zone Map available from the U.S. National Arboretum at www.usna.usda.gov/Hardzone/. Bassuk and others (2003) recommend regarding the site as one zone colder than listed if planting involves above-ground containers, because trees in containers are more susceptible to cold winter temperatures.

Sunlight Exposure

Evaluate the site to determine how much sun is received in the planting area during the growing season. This will determine what species can be planted there. Consider that a site has full sun if it receives more than 6 hours of direct sunlight. Partial sun means less than 6 hours of direct sun or filtered light for most of the day (as is common under a tree with fine textured leaves). A shady site receives little or no direct sunlight, or less than 6 hours of filtered light. Key elements to help determine sun exposure in the field are aspect and presence of structures that may block sunlight. For example, an east-facing planting area would receive morning sun (part sun), but if blocked by a nearby building would be considered shady.

Microclimate Features

Important microclimate factors to note include high wind exposure and excessive heat (re-reflected heat load). Signs of excessive wind include trees that are leaning or growing in the same direction, and plants with stunted growth on the wind-facing side. Sites that are commonly very windy include hilltop planting areas and urban sites where wind is funneled between tall buildings (e.g., wind tunnels). Reflected and reradiated heat loads from pavement, cars, buildings, and other urban surfaces can cause a tree to heat up and lose water at a faster-than-normal rate (Bassuk and others, 2003). These areas are typically south-facing, and on sunny days are noticeably warmer than nearby spots. If either of these microclimate factors exist in the planting area, tree species that are tolerant of drought must be chosen.

Topography

Steep Slopes

Note the presence of any steep slopes (typically defined as greater than 15%) and mark them on the site sketch. Steep slopes can make access difficult for planting and may require special planting techniques. Species planted on slopes should be more resistant to drought, as they will dry out faster. Also, special care should be taken not to disturb slopes during site preparation and planting, to prevent soil erosion.

Low-Lying Areas

Note the presence of any low-lying areas and mark them on the site sketch. Low-lying areas may be more evident during or after a rainfall since they collect water during storms. Trees can be planted in low-lying areas and used to treat storm water runoff, provided the species selected are tolerant of some standing water.

Vegetation

Regional Forest Association

Record the regional forest association, which indicates the climax or dominant species that characterize the types of plants found there. A useful source is a map of Küchler's Potential Natural Vegetation Groups, available from the USDA Forest Service at www.fs.fed.us/fire/fuelman/pnv.htm. Tree species that are dominant in a regional reference forest may be listed instead. This information is used to help select species of trees and shrubs to plant, particularly when the goal is to reforest an entire site.

Current Vegetative Cover

Note the type(s) of vegetation that are currently present in the planting area and the percent coverage, including turf, other herbaceous plants, trees, shrubs, or none. If any existing trees or shrubs are to be preserved, the species should be recorded on the field sheet. Note the presence and density (% coverage of the site) of all invasive plant species or noxious weeds present.

The current vegetative cover helps determine what type of vegetation removal or site preparation is needed before planting. Recording existing tree species at the planting area is also helpful to determine if the planting area is a good candidate for natural regeneration. Generally, any species located within 300 feet can be a seed source (Hairston-Strang, 2005). If existing trees and shrubs will be preserved, appropriate site preparation and planting techniques should be chosen to protect these trees. The type and density of invasive plant species will determine if control is necessary, and will help to select the type of control methods.

Adjacent Vegetative Cover

Note the dominant species present in any forest area adjacent to the planting area, if one exists. Also note the presence and density (percent coverage of the site) of invasive plant species or noxious weeds present adjacent to the planting area. Recording species present at an adjacent forested site gives an idea of what species might regenerate naturally over time due to the presence of a nearby seed source. Key things to look for include the presence of (1) light-seeded species (e.g., maple, sycamore, ash, pine, yellow poplar) upwind of the site (can be fairly far away), or (2) heavy-seeded species (e.g., oaks, hickories) upslope within 300 feet (Hairston-Strang, 2005). Presence of invasive plants adjacent to the planting area is usually an indicator that invasive plant control will be necessary at the planting site.

Soils

Soil characteristics, such as drainage, compaction, pH, and quality, should be evaluated at several sampling locations across the site, as characteristics of urban soils can vary greatly, even over a short distance. Record the findings for each sample location on the field form, check off the appropriate box based on the average condition, and record sample locations and results on the site sketch if results are highly variable.

Texture

Soil texture may be predominately sandy or clayey, or be a mixture of sand, silt, and clay, known as loam. Check the soil texture using the texture-by-feel technique and record the results. Sandy soils have a gritty feel and will not form a ball when moist. Clayey soils are sticky and plastic when moist, will form a strong ball resistant to breaking, and will provide a thin ribbon over 2 inches long. Identifying soil texture is important so that tree species that are tolerant of the soil texture may be chosen.

Drainage

Soil drainage can generally fall into one of three categories: poor, moderate, and excessive. To check drainage in the field, dig a hole 12 to 15 inches deep and remove a large handful of soil for examination. Soils with grey mottling or a foul odor indicate poor drainage. Other indicators of poor drainage include presence of plants that grow in poorly drained soils, and presence of low-lying areas that collect runoff.

To more accurately classify the site soil into one of the three drainage categories, dig a hole 12 inches deep and fill with water. Allow the water to drain completely, then refill the pit with water, and measure the depth of water in the pit. After 15 minutes, note the depth of water and calculate the rate of drainage in inches per hour. If water drainage is less than 1 inch per hour, the site is poorly drained. If drainage ranges from 1 to 6 inches per hour, soil drainage is considered moderate. If faster than 6 inches per hour, soil drainage is classified as excessive. Evaluating soil drainage is important so that tree species that are tolerant of the site drainage may be chosen.

Compaction

Soil compaction can be measured in one of several ways. The “screwdriver test” is the simplest and quickest method. Test the soil by inserting a screwdriver into the soil surface (this works best if done 2 days after a rainfall during the growing season). If the screwdriver goes into the soil easily, the soil has minimal or no compaction. If the screwdriver can be pushed into the soil, but requires some pressure, the soil is moderately compacted. If the screwdriver cannot be driven into the soil by hand, the soil is severely compacted.

The screwdriver test is useful in assessing surface compaction but may not detect deeper compacted layers, such as buried pavement, rubble, or compacted clay beneath the surface soil. Using a similar approach, it may be useful to test for subsurface soil compaction by using a 2- to 3-foot piece of 3/8-inch rebar and a small sledgehammer. In this way, the same qualitative evaluation can be made to a greater depth than is possible with the screwdriver test.

Another similar test is to dig a hole 2 feet deep with a shovel. The level of soil compaction is directly related to the difficulty encountered in digging the hole. For example, if the digging is easy, no compaction is present. If the digging is difficult or impossible, soils are severely compacted. A soil auger may also be used to test compaction. A dutch or Edelman auger is particularly useful for wet, clay, or heavily rooted soils.

More detailed tests of soil compaction include penetrometer readings and soil bulk density analysis. Because soil penetrometer readings are strongly related to soil moisture, penetrometer readings should be taken 24 hours after a hard rain (which may limit its utility during the URSA). At each sample site, record the average depth of penetration at which the probe measurement exceeds 300 pounds per square inch (Duiker, 2002). The most expensive but accurate test is to take soil cores and send them to a lab for analysis of bulk soil density. Evaluating soil compaction is important so that tree species that are tolerant of compaction may be chosen, soils can be amended before planting, or both.

pH

Test the soil pH at several spots in the planting area using a test kit, record the findings on the field form, and check off the appropriate box based on the average soil pH. If pH is highly variable, mark the sample locations and readings on the site sketch. Areas near buildings or pavement may test very alkaline due to building rubble so be sure to include these areas in the sampling if trees will be planted nearby. Rapid soil test kits for pH are available from county Cooperative Extension offices or home and garden centers. Evaluating soil pH is important so that tree species that are tolerant of the soil pH may be chosen.

Other Soil Features

Record any additional soil features of note, such as active or severe erosion, potential soil contamination, recent construction or soil disturbance, and debris or rubble in soil. If erosion is present, note the extent and severity of erosion, as well as the location and size of any rills, gullies, or soil slumping. Potential soil contamination may be indicated by the presence of drums containing hazardous or unidentified material; evidence of past dumping of restaurant waste, oil, construction debris or other materials; or unusual coloration of soil layers. Evidence of recent cuts or fills or recent construction activity includes buried trunk flares on existing trees, soil layers that are noticeably lighter in color than lower layers, absence of highly organic topsoil layer, and presence of newly paved surfaces or construction debris.

Presence of any of these soil features may indicate that some action is necessary to address impacts before planting. For example, erosion caused by excessive storm water runoff should be addressed by actions that eliminate the runoff source, or divert or infiltrate runoff at the site. If a site is suspected of contamination, further investigation should be conducted before proceeding with the project (e.g., research the site history, consult with landowner, conduct an environmental site assessment, pursue cleanup options). If soils are very disturbed amendments may be needed, or it may be necessary to bring in new soil.

Soil Chemistry (Optional)

The field crew may also want to test soil quality to determine specific nutrient, organic matter, and mineral deficiencies, or confirm soil contamination. Soil samples may be sent to a lab to be analyzed for organic matter content, salt content, and availability of key nutrients such as phosphorus, potassium, calcium, and magnesium. Soil quality testing need not be expensive—check with county Cooperative Extension offices to see if they provide low-cost or free soil testing. Alternatively, a visual assessment of soil quality can be made based on the condition of existing vegetation, presence of an organic topsoil layer, number of earthworms present, or other factors. Soil quality results should be recorded in the soil quality portion of the field form.

Hydrology

Site Hydrology

Note whether the planting area is an upland or riparian site. For riparian sites where planting is proposed on both stream banks, the hydrology section should be filled out separately for each bank. The blank space at the bottom of the hydrology section may be used to record data for the opposite bank.

Storm Water Runoff to Planting Site

Storm water flow to the planting site may be in a pipe or open channel, or be shallow concentrated flow or sheetflow. Note all the types of storm water runoff that flow to the planting site.

To determine if runoff bypasses the site in a pipe, look for storm sewer manholes, and follow their path (typically spaced at 200 foot to 400 intervals) to see where the runoff travels. For riparian areas, check for storm water pipe outfalls to the stream. Storm drain mapping from the local public works department may also be used to locate the storm sewers. To determine if an upslope drainage area discharges directly to a planting area, look for pipe outfalls to the site, and note the diameter of any pipe outfalls found (pipe size is related to the area drained). Walk around the entire planting area to look for open channels that direct flow around or across the planting area.

Runoff that is not contained in a pipe or open channel can either be shallow concentrated flow or sheetflow. Shallow concentrated flow typically forms when runoff travels over pervious surfaces greater than 150 feet, or impervious surfaces greater than 75 feet. Common indicators of shallow concentrated flow include rills, gullies, erosion, and sediment deposits. Sheetflow can only be maintained over about 150 feet of pervious surface or 75 feet of impervious surface before it starts to concentrate. These flow patterns are best observed at the site during a storm event.

Storm water runoff information is used to make decisions about whether and how to modify site drainage to treat storm water using trees or other methods, and to moderate the water balance at the site for trees and shrubs. The volume of storm water flow entering the planting area determines whether a site is currently at, under, or over its capacity to treat storm water runoff.

Contributing Flow Length

The contributing flow length is the longest distance over which runoff travels before it enters the planting area. For larger planting areas, it is the distance runoff travels before leaving the planting area, by entering an open channel, an inlet, or a different portion of the property. To measure the contributing flow length, walk a path from the point that is most hydraulically distant (typically the point on the farthest upgradient ridgeline) to the lowest point of entry to the planting area (or to the lowest point or outlet of larger planting areas). If conducting this assessment during a dry period, it may be helpful to use a tennis ball or a table tennis ball to determine which way runoff would flow by placing the ball on the ground at the farthest upgradient point and observing which direction it rolls. When walking the contributing flow length, note the slope and the dominant cover type. Sketch the contributing flow length on the URSA field sheet, marking any changes in land cover or slope along the way.

The contributing flow length is used to determine or verify if runoff to the planting site is sheetflow or shallow concentrated flow. If the contributing flow length is less than 75 feet over an impervious surface or less than 150 feet over a pervious surface, the runoff will likely remain as sheetflow and will not concentrate.

Floodplain Connection (Riparian Areas Only)

If the planting area is riparian, note the presence of levees or other structures that restrict flood flows onto the floodplain, and the bank height. The stream order will already have been recorded in the office but may be verified in the field. If desired, the depth to seasonal high water table can be measured using a soil auger and observing wetness, mottling, or gleying. Test pits or monitoring wells can also be used to measure depth to groundwater, if desired, but may be cost-prohibitive.

In urban areas, floodplains tend to be drier than their rural counterparts due to three factors: water table is lower due to reduced groundwater flows, floodplains are disconnected from their streams due to stream incision or construction of levees, and storm water runoff bypasses the buffer area by being piped directly to the stream. In these areas, upland species may be more suited to the hydrology of the site than floodplain species. Therefore, it is important to verify the hydrologic conditions at the site. In general, first order streams with bank height greater than 3 feet, and second order or higher streams with bank height greater than 5 feet, are likely to be disconnected from the floodplain (Schueler and Brown, 2004). Depth to groundwater is a good indicator of floodplain connection. The depth to seasonal high water table can be used as a general estimate of depth to groundwater, since groundwater elevations do not fluctuate substantially over the year (Palone and Todd, 1998).

Potential Planting Conflicts

This section is used to record the presence of potential planting conflicts at the site, in order to identify if site preparation or other special techniques are needed to reduce these conflicts and improve growing conditions for the trees.

Space Limitations

Note the presence of aboveground or belowground space limitations, such as overhead wires, pavement, structures, signs, lighting, existing trees, or underground utilities. Mark the location on the site sketch, and record the height of overhead wires, signs, and lighting. Utilities such as gas lines will often be marked (to warn people not to dig), while presence of electric and sewer lines may be less apparent. Look for manholes and sewer inlets to estimate location of sewers, consult the property owner, or estimate locations based on utility maps. Exact locations of utilities will be needed before site preparation and planting by calling the local department responsible for locating utilities (Miss Utility in the Mid-Atlantic) to mark their location at the site.

Presence of infrastructure may indicate that the use of alternative designs, materials, or maintenance practices are recommended to accommodate both trees and infrastructure without conflict. Existing infrastructure can limit the available space for planting, if setbacks are necessary to avoid future conflicts between trees and infrastructure as the trees mature. By recording the location of existing infrastructure and factoring in appropriate setbacks for trees (where applicable), a more accurate estimate of the area available for planting can be derived. Setbacks may be based on what is recommended by local utilities or required by local ordinance.

Other Limiting Factors

Record the presence of any other limiting factors such as these:

- Trash dumping and debris
- Deer, beaver, or other animal impacts
- Mowing conflicts
- Presence of wetlands
- Insects or disease
- Heavy pedestrian traffic

Record the type of trash present, its source (if known), and estimate how many truckloads are needed to remove it, to assist in planning cleanups. Note any evidence of impacts from deer, beavers, neighborhood pets, rodents, or other animals. This may include the presence of animal droppings, removal of bark on existing trees, or presence of nearby beaver dams. Impacts from deer are evidenced by sparse or nonexistent understory, a distinct browse line, or presence of nonpreferred browse species in existing or adjacent forests. Wetland indicators include the presence of wetland vegetation, poorly drained soils with grey mottling, foul odor, or standing water. If existing trees show evidence of disease or insect damage, record the type and extent of damage and the species affected. If heavy pedestrian traffic is evident, mark the location of pathways on the site sketch.

Other limiting factors will need to be addressed before planting. If trash dumping and debris is present, it will need to be removed. If animal impacts are present, methods to control populations or reduce their impact on trees should be evaluated. If the site is currently being mowed, provisions will be necessary to change the mowing practices after planting. This may include posting signs or using fencing or mulch to keep mowers far away from trees. If a wetland is suspected to be present at the site, it may be necessary to conduct a wetland delineation and obtain a permit before starting the project. This will also affect species selection for the site. In areas with heavy pedestrian traffic, the site should be designed to minimize impacts to trees, and may include use of mulch, fencing, or other protective measure.

Local Ordinance Setbacks

This section should be completed before going out in the field, to record setbacks between trees and infrastructure that are mandated by local ordinance or utility. Most setback requirements can be found in local ordinances related to site or subdivision development. Also check with local utility companies to determine their clearance requirements for different voltage wires. The purpose of this section is twofold: first, it ensures the designer complies with any required local setbacks; and, second, it allows analysis of required local setbacks to suggest changes to local ordinances to allow for better tree growth or incorporate more trees into the urban landscape.

Planting and Maintenance Logistics

Site Access

Indicate whether access to the site allows for delivery of planting materials, temporary storage of planting materials, room to maneuver heavy equipment, volunteer parking, and facilities for volunteers. This determines the methods and equipment to use in site preparation and planting. For example, if the site is not accessible by heavy equipment due to steep slopes, planting, soil amendments, and invasive plant removal will need to be done by hand. If volunteers will be used for planting, it is important to scope out facilities and parking ahead of time.

Water Source

Note the presence and type of any water sources. Sources may include rainfall, storm water runoff (indicated by shallow concentrated flow, sheetflow, or outfall to site in the Hydrology section of the field sheet), nearby hose hook-up (note distance from planting area), stream or overbank flow (in riparian areas), irrigation system, or nearby fire hydrant (work with local fire department to water trees). It is important to evaluate water sources since newly planted trees must be watered regularly the first year or two after planting. The existence of a nearby water source for irrigation makes this critical maintenance task much easier.

Party Responsible for Maintenance

The field crew should identify the land owner, local volunteer group, or homeowners association that is responsible for maintenance before going out to the site. It is important to designate up front the party responsible for maintaining the new plantings, to ensure that maintenance such as watering, mulching, weed control, removing tree shelters, and adjusting stakes will actually occur. The responsible party should be informed about proper maintenance techniques and the desired schedule.

Site Sketch

The field crew should quickly sketch the site, including the following features as a minimum:

- Property boundary, landmark features (e.g., roads, streams) and adjacent land use and cover
- Boundary and approximate dimensions of proposed planting area
- Variations in sun exposure, microclimate, and topography within planting area
- Current vegetative cover, location of trees to be preserved, and invasive species
- Location and results of soil samples (if variable)
- Flow paths to planting area and contributing flow length, location of outfalls
- Above or below ground space limitations (e.g., utilities, structures)
- Other limiting factors (e.g., trash dumping, pedestrian paths)
- Water source and access points
- Scale and north arrow

The site sketch will ultimately be the foundation for the more detailed planting plan. An example URSA sketch is provided in Figure 2. Specific information on how to use the URSA data to develop a planting plan is provided in Chapter 3.

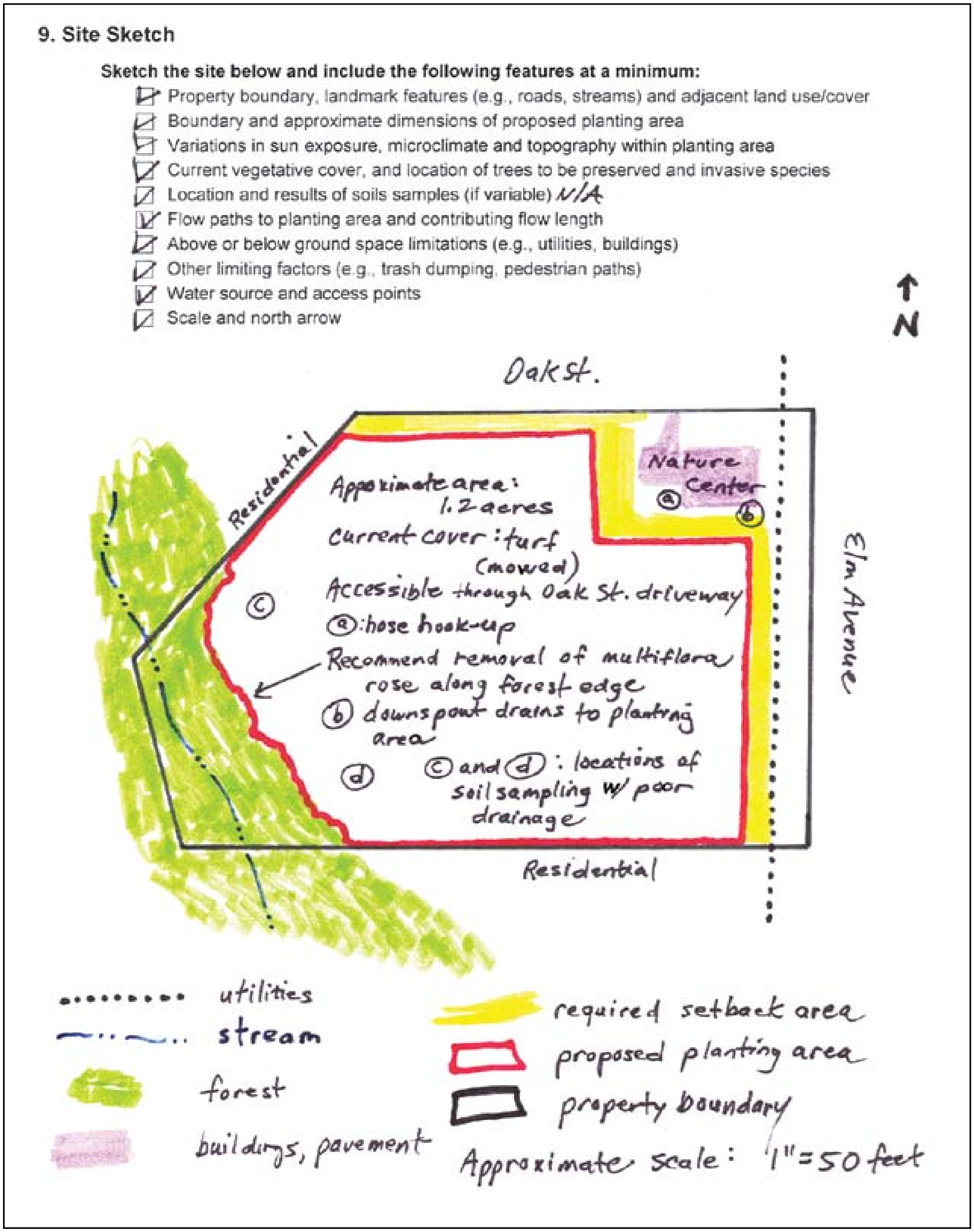

Figure 2. The site sketch for an urban reforestation site assessment becomes the foundation for a detailed planting plan.

Chapter 3. Basic Planting Design

Successful urban tree planting involves selecting appropriate species and plant materials, spacing plants appropriately, and developing a realistic planting plan, including a cost estimate. Each planting decision can be made using data gathered during the URSA (Chapter 2).

This chapter describes the factors to consider in developing the planting plan for a site.

Selecting Plant Species

The primary purpose of a planting plan is to determine what species of trees and shrubs to plant. Planting the right tree in the right place is a simple but often overlooked strategy to improve the survival of urban trees, even under difficult growing conditions, and to yield the greatest benefit from the tree. Proper species selection will ultimately save money through lower maintenance and replacement costs and higher landscaping value (Akbari and others, 1992 and ISA, 2000a). Species selection is based on site-specific information evaluated at each planting area, as well as on planting objectives. This section summarizes key factors in selecting the right species for the planting area.

Factors Influencing Species Selection

Factors influencing species selection include environmental conditions at the planting area and desired tree functions. In addition, native species are often recommended because they are better adapted to local conditions and generally require less maintenance. However, severe site conditions in urban environments may dictate the selection of well-adapted, hardy, nonnative species, provided they are not invasive. Environmental conditions and desired tree functions are described below.

Environmental conditions at the planting area are an important factor and are usually evaluated through the URSA (Chapter 2). Table 4 summarizes these environmental conditions and provides guidance on how to use them to select trees species from the Urban Tree Selection Guide in Appendix B. In general, tree species should be adapted to the local climate, as well as to the specific soil type, soil drainage, soil pH, and sun exposure present at the site. Trees should be hardy and resistant to any noted disease or pests in the area, and be able to tolerate observed urban conditions, such as compacted soil. Trees should also be appropriate for the intended use of the site and should, at maturity, fit the planting space provided, considering both above ground and below ground limitations.

Species may also be selected to promote tree characteristics that provide a certain function or benefit at the site, such as a high Leaf Area Index (LAI). The LAI of a tree represents the relative surface area of leaves and branches. The LAI is important in terms of potential for trapping small rainfall events and thus potential for reduction of storm water runoff. LAI is also an important factor in a tree's ability to yield various benefits of air pollution reduction. Values for LAI for various common tree species are currently under development. Other desirable characteristics may include these:

- Fast growth rate
- Ornamental traits – seasonal foliage color, blooming season, and characteristics of flowers
- Large size (> 50 feet in height)

- Specific form (e.g., pyramidal, upright)
- Wide-spreading canopy to provide shade
- Provides food for wildlife (fruits, nuts)

Table 4. Environmental Conditions That Affect Species Selection

Environmental Conditions from URSA (Chapter 2)	Species Selection Guidance	Corresponding Fields in Urban Tree Selection Guide (Appendix B)
USDA plant hardiness zone	Select species tolerant of planting area hardiness zone.	Hardiness zone
Sunlight exposure	Select species tolerant of sun exposure at site.	Sun exposure
Microclimate features	If high wind exposure or re-reflected heat load, select species tolerant of drought.	Drought tolerance
Topography	If low-lying areas, select species tolerant of flooding. If steep slopes, select species tolerant of drought.	Drought tolerance Flood tolerance
Regional forest association	Use species from regional forest association as preliminary target species list.	None
Soil texture	Select species tolerant of soil texture at the site.	Soil components
Soil drainage	Select species tolerant of soil drainage at the site.	Soil moisture
Soil compaction	Select species tolerant of soil compaction at the site	Soil compaction
Soil pH	Select species tolerant of soil pH at the site.	pH level
Soil chemistry	If soils have high salt content, select species tolerant of salt.	Salt tolerance
Storm water runoff to planting site	If site is under-capacity, select species tolerant of drought. If site is at-capacity or over-capacity, select species tolerant of flooding (see Chapter 4 for guidance on identifying these types of sites from URSA data).	Drought tolerance Flood tolerance
Floodplain connection	If floodplain is connected, select species tolerant of flooding.	Flood tolerance
Space limitations	If infrastructure is present, select species appropriate for the planting space (see Chapter 4 for specific guidance).	Height Canopy spread Form or habit Root structure
Other limiting factors	If other limiting factors are present, select species that are tolerant of these factors (see Chapter 4 for specific guidance).	Flood tolerance Pest or disease tolerance

The Urban Tree Selection Guide in Appendix B can be used to select tree and shrub species that are appropriate for a given site, based on their tolerance for environmental conditions and tree characteristics discussed above. The Urban Tree Selection Guide is compiled from multiple sources and is most applicable to the Northeast and Midwest regions of the United States. Site designers should always consult with local horticulturists, arborists, landscape architects, or other foresters who are familiar with the local conditions to refine the tree species selection and better assure the success of the project.

The Importance of Diversity

Maintaining a high level of species diversity in urban forests is important to prevent forest mortality due to species-specific insect or disease outbreaks (e.g., Dutch elm disease). A good rule of thumb is to plant a minimum of five species and set a minimum and maximum number of each species (NC DENR, 2004; ACB, 2000; CBF, 2001). When re-creating a local forest association, a diverse mix of 10-12 species is recommended, including understory trees and shrubs (NC DENR, 2004). As a caveat, the designer should always keep in mind the project goals, setting, and the availability of plant materials, when determining the number of species to plant. Just as too few species can be a problem, selecting too many species can complicate project implementation.

In addition to species diversity, it is also important to create a diversity of habitats to maximize wildlife benefits. In a forest, this means having vertical layers of vegetative cover, including canopy, midstory, understory, and ground cover. If desired, a shrub layer can be planted along with larger trees at the time of planting to increase diversity and create an understory. If the planting plan seeks to establish both canopy species and understory trees, a rule of thumb is to plant at least three or four understory trees for every canopy tree to provide structural diversity similar to mature forests (NC DENR, 2004; Palone and Todd, 1998).

Choosing Plant Materials

Tree and shrub materials are available for purchase in three basic nursery production forms: balled and burlapped, bare root, and container grown stock (Figure 3). Each type of plant material varies in size, cost, survival rates, planting procedures, and establishment success (Buckstrup and Bassuk, 2003; Palone and Todd, 1998; Tree Trust, 2001; WSAHGP, 2002). Some key advantages and disadvantages of the three types of plant materials are compiled in Table 5.

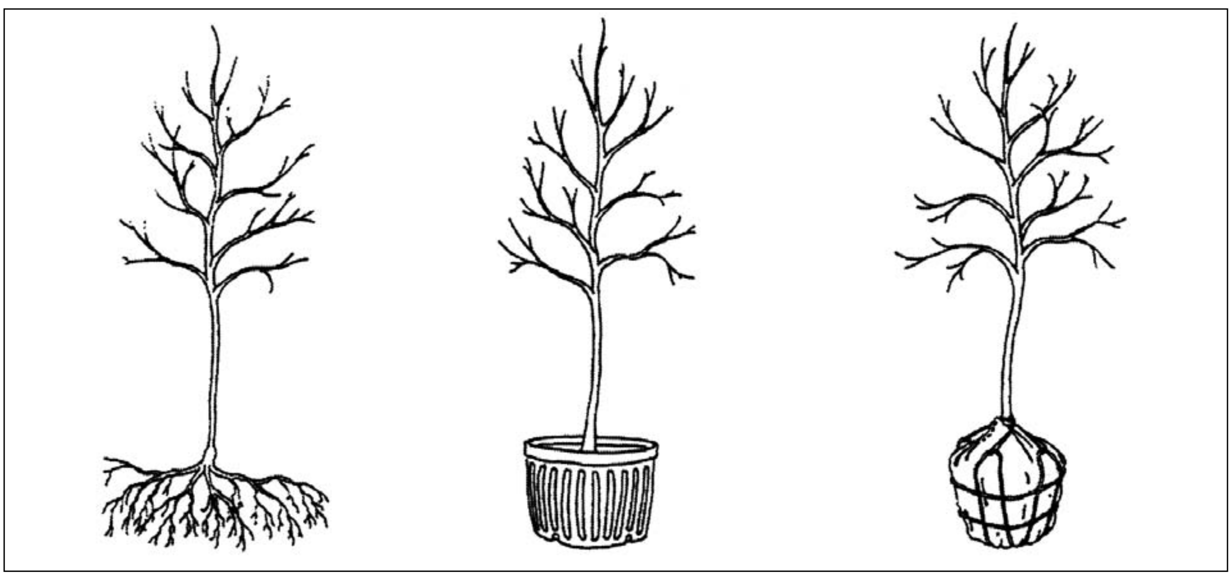

Figure 3. Three types of plant materials are available: (from left) bare root, container grown, and balled and burlapped (Illustration by Nina DiRenzo, used with permission from Nina Bassuk, Director of Cornell Urban Horticulture Institute)

Table 5. Advantages and Disadvantages of Various Plant Materials			
Type of Plant Material	**Size Range**	**Advantages**	**Disadvantages**
Bare root	Seedlings up to 2-inch caliper	• Inexpensive • Easy to plant and transport • Condition of roots is easy to evaluate • Soil interface problems are not an issue	• Limited planting window • Not appropriate for all species • Requires special storage/handling • More subject to accidental damage by mowers
Container grown	Seedlings up to 2-inch caliper	• Longer planting window • Readily available • Visible to maintenance crews	• Moderate to high cost • Roots may be pot-bound • May require more watering after planting
Balled and burlapped	1- to 4-inch caliper	• Longer planting window than bare root • Larger size makes plants more resistant to damage • Heights are generally above most competing plants	• Most expensive • Difficult to plant without machinery • Cannot see condition of roots

Source: Buckstrup and Bassuk (2003), Hairston-Strang (2005), Palone and Todd (1998), Tree Trust (2001), and WSAHGP (2002)

Bare root stock are usually small trees that are dug out in fall or early spring and stored with no soil attached to their roots. Due to their small size and manageability, bare root trees are very easy to plant. Roots must be kept moist until planting and should be planted in spring while they are dormant, to avoid drying out. **Container grown trees** are trees that have been growing in a container for several months to a year. They can range in size from seedlings in gallon pots to 4- to 5-foot trees in larger pots. Container grown trees are considered easy to plant and establish in almost any season. Balled and burlapped trees are trees that are dug, wrapped in burlap, and kept in the nursery for an additional period of time. **Balled and burlapped trees** can be very large and are difficult to plant without heavy equipment.

Tree sizes range from seedlings up to 4-inch caliper. Larger trees and shrubs are sold by the caliper inch, which is defined as the diameter of the stem measured 6 inches above the ground (or 12 inches above the ground for trees greater than 4 inches in diameter). Trees larger than 2-inch caliper are more expensive but may work best where intensive uses are anticipated, as in urban parks. Larger plant material may also attain the desired planting goals more rapidly because they mature rapidly.

Generally the most cost effective and successful type of plant material is bare root seedlings (Buckstrup and Bassuk, 2000; NC DENR, 2004), provided special techniques are used to prevent root desiccation (see Chapter 6 for information on Storing Plant Materials). Bare root material grows relatively rapidly after the root system is established, reaching canopy closure soon after similar size balled and burlapped material (Palone and Todd, 1998). One drawback is that bare root seedlings are not as visible as other plant materials, are more likely to be damaged by mowing and maintenance equipment, and generally take more effort to protect.

For urban tree plantings, a mix of bare root seedlings and larger trees may be the best approach (Doherty and others, 2003; Palone and Todd, 1998). One option can be large trees on the outer edge of a planting to mark the location, with bare root seedlings planted inside. Ultimately, planting strategies are largely determined by the extent of available funding.

Plant materials should be grown locally or ordered from a local nursery so they are adapted to regional conditions. Trees that have been properly trained and pruned in the nursery require less pruning after planting, become established more quickly, and are more resistant to damage from winds and other stressors (Mock, 2002). Reputable nurseries should adhere to landscape plant specifications set forth in the *American Standard for Nursery Stock* (ANLA, 2004). However, these numeric standards are not quality based, so individual trees should also be inspected to be sure they are of high quality. Guidance on inspecting nursery stock is provided in Chapter 6, and in ISA (2000b), and Polomski and Shaughnessy (1999).

Determining Plant Density

The layout of trees and shrubs at the planting site will vary with the ultimate goal of a planting project (e.g., street tree plantings, park, forest). For tree plantings along streets or other sites constrained by infrastructure, plant spacing is determined by proximity to infrastructure and ultimate expansion of the tree canopy. For example, spacing of 30 to 50 feet is typically recommended for a large street tree (i.e., over 50 feet high when mature).

When planting in larger spaces, such as a park, reforestation of the entire area will provide the most benefits in terms of cooling, storm water reduction, and habitat. Where this is not possible due to conflicting uses or site constraints, planting trees in clusters or groves is recommended. Planting trees in clusters improves plant health, species richness, and habitat diversity (Hobbs, 1988; Tree Trust, 2001; Sudbrock, 1996; WSAHGP, 2002). Trees that are planted in interconnected soil volumes will grow larger than if planted singly, because interconnected soil volumes result in a more even distribution of water and roots (Urban, 1999). The spacing of plants within the forest, tree cluster, or other layout is an important element of planting design, and will ultimately determine how many trees and shrubs are needed for the planting.

Plant spacing is based on the desired stem density, and should also account for survival rates of the stock and species selected. The project budget and maintenance needs can also affect plant spacing. For example, where mowing is necessary to control invasive plants, spacing should allow mowing between individual trees. In general, more dense spacing (more than 400 trees per acre) helps to achieve forest canopy closure more quickly, which in turn reduces competition from weeds (Hairston-Strang, 2005). However, higher densities (more than 500 trees per acre) should be thinned later to improve the quality of the stand by promoting larger trees (Hairston-Strang, 2005). When planting larger stock where the goal is landscaping rather than forest, spacing of 30 to 50 feet is recommended for large trees. Three potential spacing options for different plant materials are provided in Table 6.

Table 6. Example Planting Densities for Various Size Trees			
Scenario	**Tree Size**	**Spacing (feet)**	**Resulting Stem Density (trees per acre)**
1	Seedlings	8	340
2	Tree with ¾-inch d.b.h.*	14	160
3	Tree with 2 ½-inch d.b.h.*	17	150

In scenario 1, seedlings are planted at a greater density than what is ultimately desired, to allow for losses due to competition, stress, and herbivory. Using an average survival rate of 50%, plant spacing of 8 by 8 feet results in sufficient stem density upon maturity.

In scenario 2, planting density is somewhat higher than the stem density desired, to account for losses due to competition, stress, and herbivory. Based on a survival rate of 75%, plant spacing of 14 by 14 feet achieves the desired stem density. The plant material in this scenario is at least several feet high and about three quarters of an inch in diameter.

In scenario 3, spacing is based on the ultimate desired stem density since these larger plant materials will be most likely to survive. In this approach, the canopy, midstory, and understory may all be planted at once in their final locations. The 17- by 17-foot spacing used results in a canopy tree density that is comparable to that typically found in a mature forest.

Source: ACB (2000)
* d.b.h. = diameter at breast height

For large planting projects that use a mix of stock, species, and plant sizes, a general rule of thumb for estimating the number of trees and shrubs needed is provided below (from ACB, 2000):

$$\text{Number of plants needed} = \frac{\text{length (feet)} \times \text{width (feet) of planting area}}{\text{50 (square feet)}}$$

This formula assumes that each randomly planted tree or shrub occupies an average space of 50 square feet and that average trunk spacing is 10 feet. Using this rule of thumb, a tree mortality rate of up to 40% can be absorbed by the growing forest system.

There are two schools of thought regarding plant layout and spacing when re-creating a forest: **uniform plant distribution** and **random plant distribution** (Palone and Todd 1998). Layout and maintenance are much simpler with uniform distribution, particularly when volunteer labor is used for installation. Mixing species randomly within the planting can enhance variability and the natural appearance of a uniform plant distribution planting. A disadvantage to uniform planting is that the reforestation project may appear “too structured and unnatural.” Over time, however, tree mortality will compensate for uniformity and leave vacant spaces between trees, as well as opportunities for germination of seed dispersed naturally from adjacent trees.

Random distribution provides the initial “natural spacing” appearance, but may create difficulties when trying to perform survivability counts, as well as maintenance activities, such as mulching (Palone and Todd, 1998). Whichever method is chosen, plant spacing should be close enough to reflect the natural forested situation observed in the local area (Palone and Todd, 1998; CBF, 2001), and provide as much canopy closure as possible in forested zones. The method should also provide enough distance for adequate plant establishment before root systems begin to compete within the limited growing space.

Planting Plan and Cost Estimate

A planting plan should be developed for each planting site based on the information collected during the URSA (Figure 4). Up to 6 hours of time may be needed to develop a planting plan for each site, depending on the size of the site. A landscape architect (LA) may use the URSA data to draw up a conceptual sketch of how the site will look when planted, and then translate this idea into a planting plan. Planting plans are essentially a blueprint of how the tree planting will be done and should contain the following minimum information (CBF, 2001; ACB, 2000):

- Map or sketch of the site with appropriately marked planting zones
- Plant species list (number, size, type of stock)
- Planting directions (spacing, layout)
- Planting instructions
- Equipment and supply list
- Site preparation instructions
- Implementation and maintenance schedule
- Cost estimate (planning-level costs for the entire project)

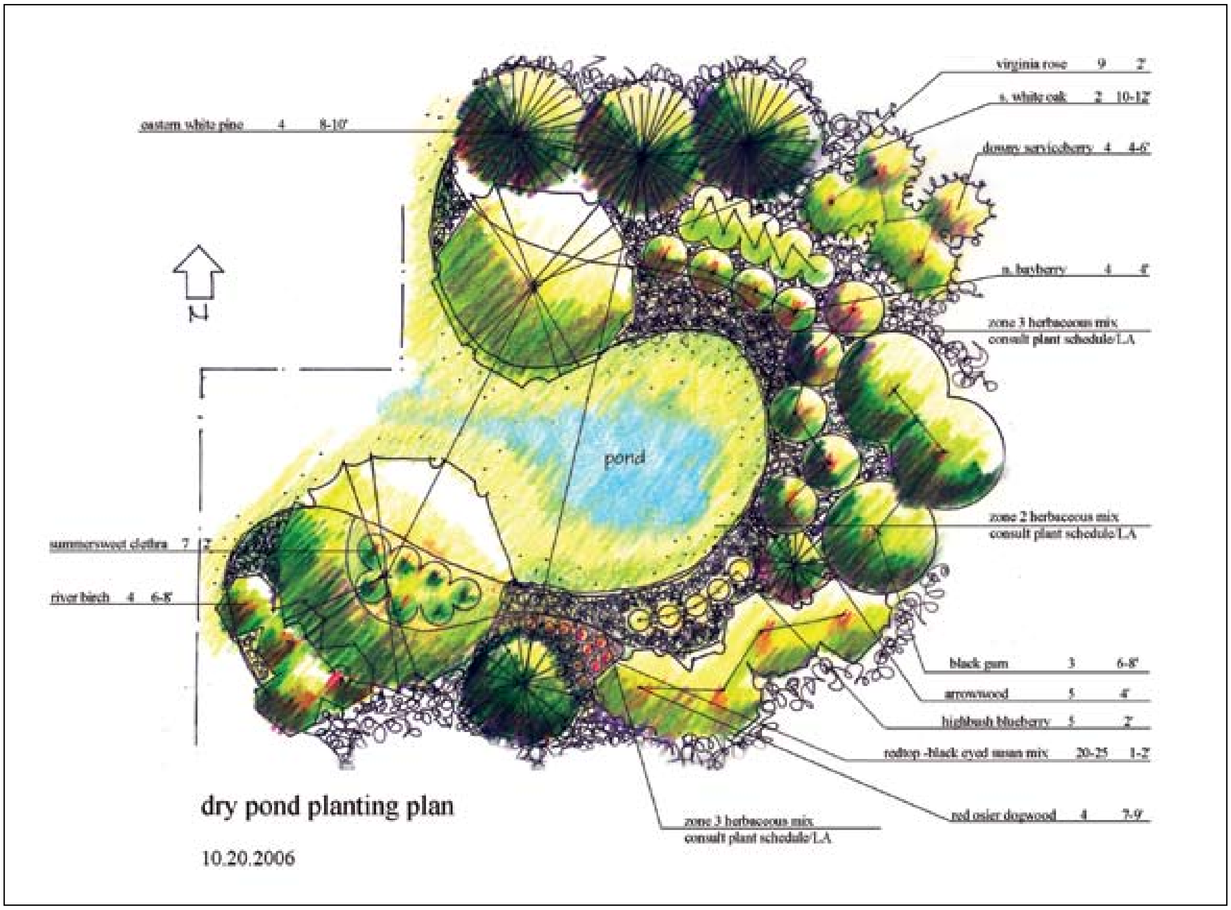

Figure 4. A planting plan for an urban reforestation site includes a map or sketch of the site showing the locations of species to be planted.

Unit costs for plant materials and supplies are provided in Table 7 to help estimate the planting project cost. The unit costs for plant materials vary depending on the size of the plant, the species, and the number purchased. Unit costs for mulch and compost depend on whether it is delivered, and the type or grade. Other cost factors include any labor, equipment, site preparation, or maintenance costs needed to ensure success. Each cost factor is discussed below, and a worksheet for estimating all project costs is provided in Appendix C.

Table 7. Estimated Unit Costs for Plant Materials and Planting Supplies

Item		Cost*
Plant Materials	Bare root trees	$0.30 --- $40.00 each
	Container grown trees	$2.50 --- $80.00 each
	Balled and burlapped trees	$35.00 -- $400.00 each
Supplies	Tree shelters (12 to 72 inches)	$1.00 ---- $4.00 each
	Tree stakes	$1.00 ---- $2.00 each
	Mulch	$6.00 -- $20.00 per cubic yard
	Compost	$11.00 -- $20.00 per cubic yard

Source: Chollak and Rosenfeld (1998), Environmental Concern, Inc. (2005), Hairston-Strang (2005), Octoraro Native Plant Nursery (2004), Palone and Todd (1998), and Tree Trust (2001).
*Cost does not include installation.

Unit costs for plant materials in Table 7 do not include installation costs. For example, the installed cost of tree shelters ranges from $4.00 to $5.00 per tree (Hairston-Strang, 2005). Installation costs for tree planting can range from low cost hand-planting to higher cost machine planting. For bare root trees, hand planting with mattocks or dibble bars is the least expensive method, but root spread may be compromised. If power augers are used to dig planting holes, installation costs should run from $0.40 to $0.50 per tree, making the installed cost $0.70 to $40.50 per tree. Installation of container grown trees will be similar to the costs associated with bare root planting. Balled and burlapped trees will generally cost the most to install, ranging from $18.00 to $50.00 per tree, depending upon method, size of plant, and source (Palone and Todd, 1998).

Installation costs will vary greatly depending on the cost of the given labor source used: agency staff, contracted labor, watershed groups, or volunteers. The cost of local agency staff is usually moderate. Staff of watershed groups have a relatively low labor cost. Volunteers are certainly the lowest cost labor type but most arrive with low skill levels and require additional training. Using volunteer labor greatly reduces the costs involved in tree planting, but is never without charge. A modest investment is needed to recruit, train, coordinate, and provide refreshments for volunteers.

Equipment costs also vary greatly depending on the size of plant material and planting area, labor type, and whether the equipment is purchased, rented, or donated. Equipment can include mechanical tree planters, power augers for digging holes, delivery trucks, or a Bush Hog for removing unwanted plants. Small equipment that may be needed for site preparation and planting include mattocks or shovels, wheelbarrows, swinging blades, work boots, gloves, measuring tapes, hammers, and flagging.

Site preparation cost estimates are provided in Chapter 5. Maintenance costs will vary by site and can include mowing, pruning, mulching, weed control, watering, or supplemental plantings.

Chapter 4. Special Considerations for Urban Tree Planting

To grow, a tree needs the right balance of sunlight, water, rooting space, and soil nutrients. The urban planting environment often lacks many of these growth factors and imposes unique stresses on trees. Conflicts between trees and infrastructure (e.g., utilities and pavement) may damage trees and infrastructure, and result in tree removal. It is important to evaluate the potential stressors and conflicts present at each planting site. Most conflicts can be addressed through appropriate species selection, soil amendments, planting layout, or other special techniques.

This chapter discusses techniques to ensure adequate soil volume, effectively treat storm water, reduce infrastructure conflicts, and protect trees from other impacts.

Calculating Soil Volume

Because space is a premium in many urban areas, urban trees are typically allotted only small planting areas, regardless of the size of the tree. In addition, poor urban soil quality may further reduce the rooting volume that can actually be used by a tree. Soil is critical to tree health because it provides structure and vital water and nutrients. Several tree functions are linked to adequate root volume (Urban, 1999; VCE, 2002). Limited soil volumes, however, confine roots, restrict growth, reduce anchorage, and supply inadequate moisture and nutrients (VCE, 2002). Most urban street tree pits average only about 50 cubic feet of soil (Figure 5), while a large tree actually requires at least 400 cubic feet of usable soil (Urban, 1999). Inadequate rooting volume appears to be a contributing factor in the low life expectancy of the average urban tree, estimated at less than 10 years after planting (VCE, 2002).

Figure 5. Typical urban tree pits provide only about 50 cubic feet of soil.

When planning an urban planting project where space is limiting, it is important to evaluate how to provide the optimal soil volume for each tree. The first step is to calculate the optimal soil volume per tree. A general rule of thumb is to measure the area within the projected mature drip line of the tree and provide 2 cubic feet of usable soil per square foot (Grabosky and others, 1999; Urban, 1999). Based on this rule of thumb, Urban (1999) correlated crown projection and tree size to identify minimum required soil volume for various size trees (Figure 6).

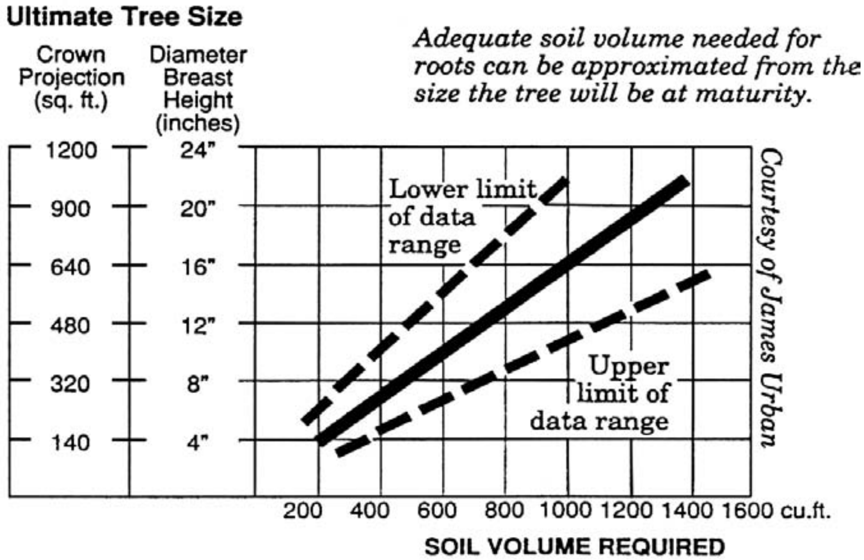

Figure 6. The soil volume required for various size trees assumes a soil depth of 3 feet. (Source: James Urban)

Trowbridge and Bassuk (2004) have developed a more detailed calculation that takes into account a tree's specific water needs, its expected water loss based on local atmospheric conditions, and its average water-holding capacity. A modified version of their soil volume equation follows.

$$\text{Soil volume} = [((3.14 \times r2) \times LAI \times ER \text{ x } 0.2) / AWHC] \times RF$$

where:

r (ft) = radius of tree canopy at maturity.

LAI = leaf area index, the ratio of total tree leaf surface area to crown projection. LAI can be derived from regional data where it exists (typical range is 1.5 to 3).

ER (ft/day) = evaporation rate, the highest mean monthly evaporation rate divided by the number of days in the month. ER can be derived from pan evaporation data (data derived from measuring evaporation in pans of water, often available from local weather stations).

AWHC = available water holding capacity, which varies by soil type but typically ranges from 10% to 20%. AWHC can be derived from testing the planting area soil.

RF (days) = rainfall frequency; the average length of a dry period in the region, with dry period being defined as a period with less than the rainfall amount that constitutes a critical rainfall event. Rainfall data are available from the National Oceanic and Atmospheric Administration, and the average should be based on at least 10 years of data.

The soil volume equation assumes that usable soil is provided in the planting area to a depth of 3 feet. The calculation and the earlier rule of thumb are based on the assumption that the soil volume provided is usable, meaning it is uncompacted, and contains adequate organic matter and nutrients. If the existing soil is unusable, it may need to be amended or replaced, either over the entire site or around individual planting holes (see Chapter 5 for information on soil amendments).

Determining the required soil volume for a planting site helps determine if existing soil and space are adequate to plant the desired number and size of trees. To determine the available soil volume at the site, multiply the planting area (minus any portions that cannot be planted due to infrastructure or conflicting use) by a rooting depth of 3 feet. If insufficient soil volume is present, the designer should decide how to redesign the planting site to provide more area or depth for tree planting or use alternative plant materials. For example, when planting in a tree lawn, the width of the tree lawn could be increased by decreasing the road width, where feasible, to provide more soil for trees. Another option is to use an alternative tree layout that allows trees to share rooting space. If the site cannot be redesigned, the number or size of trees planted at the site, or both, should be reduced to ensure that individual trees have a decent chance of survival.

Evaluating Storm Water Runoff

Too little water or too much water can cause tree mortality at urban planting sites. Too much water is often the result of storm water runoff from nearby impervious surfaces being directed towards planting areas and overwhelming the infiltration capacity of the soil or the saturation tolerance of the tree species. Too little water reaches an urban tree when rainfall that would normally soak into the ground can infiltrate only a small area around each planting pit. The rest becomes storm water runoff that is efficiently directed into nearby storm sewers, making it unavailable to tree roots (Figure 7). Designing urban planting sites for the expected volume of storm water and rainfall helps to ensure an appropriate water balance for trees and can improve water quality, as trees remove pollutants from storm water runoff. Part 1 of this manual series summarizes the water quality benefits of trees.

Figure 7. Urban trees in raised planters receive very little water from rainfall or runoff.

This section outlines a method to evaluate the capacity of planting areas to accept and treat storm water runoff from adjacent areas. This simple evaluation of storm water runoff to the site is made during the URSA (Chapter 2), and is used to identify appropriate storm water treatment and planting strategies. Table 8 provides a summary of three possible storm water treatment capacity conditions at a planting area, and corresponding storm water and planting strategies to address them. Each storm water capacity condition is discussed in more detail below.

Table 8. Storm Water Treatment Capacity Conditions of Potential Planting Sites

Capacity Condition	Site Description	Storm Water Strategy	Planting Strategy
Under capacity	Receives no runoff; runoff bypasses site in pipes or ditches, or infiltrates before reaching the site.	Daylight the pipe or split the flow.	Choose drought-tolerant species or provide irrigation.
At capacity	Receives only sheet flow; runoff travels over a relatively short distance before reaching the site.	Install filter strip with trees or plant trees behind small berm.	Plant species that are suited to the wetness of the site.
Over capacity	Receives concentrated flow; runoff travels over longer distance before reaching the site, or is directed to the site in a storm water outfall.	Install perimeter treatment practice or pipe the flow.	Plant wet-tolerant species using large stock.

Under-Capacity Sites

Under-capacity sites receive no concentrated storm water runoff or sheet flow and, consequently, provide no storm water treatment (Figure 8). Runoff from adjacent land either infiltrates before reaching the planting area, due to high soil infiltration rates, or bypasses the planting area in a pipe or ditch. Trees at under-capacity sites may require supplemental water in order to grow.

Figure 8. This under-capacity site receives no storm water runoff.

Identifying under-capacity sites

Several factors evaluated during the URSA help to determine if a planting area is under capacity for storm water treatment. The first is an evaluation of storm water runoff to the planting site. Under-capacity sites show no evidence of upgradient drainage, and have no storm water outfalls, shallow concentrated flow, or sheetflow to the site. Also, if pipes or open channels direct runoff across or around the site, the site is under capacity.

Another factor is the "contributing flow length." This is the longest distance over which runoff travels before entering the planting area. For larger planting areas, it is the distance runoff travels before leaving the planting area. Flow length should be measured by following a path from the point that is the most hydraulically distant (typically the point on the farthest upgradient ridgeline) to the lowest point of entry to the planting area, or to the lowest point on the planting area for larger sites. If the contributing flow length is less than 75 feet and is impervious (or 150 feet and pervious), the site is usually considered under capacity. Under-capacity sites also show no signs of receiving storm water runoff.

Storm water strategies

Storm water strategies for under-capacity sites where runoff bypasses the planting area involve modifying the site drainage or splitting flows to allow for some treatment of storm water. One option is to split the flow from the pipe so that a portion of the runoff is diverted into the reforestation site and travels as sheet flow, while the remainder of the runoff continues through the pipe and into the stream (also called partial daylighting). Several variables need to be analyzed to determine whether daylighting is feasible, but a rule of thumb is that daylighting works best where the site is too small to handle all of the runoff from the pipe. For more information on pipe daylighting and flow splitting, see Schueler and Brown (2004).

Planting strategies

Where storm water strategies are not pursued, the planting strategy at under-capacity sites should account for the lack of runoff at the site. Unless an adjacent water source is found, the only water source will be rainfall, and the site may be vulnerable to drought. Therefore, the species planted should be tolerant of drought (see Appendix B, Chart 1, for species tolerant to drought). A small soil berm may also be created around the planting hole to hold water near the tree.

At-Capacity Sites

At-capacity sites receive sheet flow only from adjacent land, and the amount of flow does not overwhelm the capacity of the site to treat storm water runoff (Figure 9).

Identifying at-capacity sites

Planting sites that are at capacity show no evidence of shallow concentrated flow or of upslope drainage area outfalling to the site. Sheetflow may be observed; however, sheet flow is difficult to maintain over long distances. Therefore, under this condition, the contributing flow length will be a maximum of 75 feet for impervious surfaces and a maximum of 150 feet for pervious surfaces. As the slope of the contributing flow length increases, these maximum distances will be reduced, since increasing slope will cause runoff to concentrate more quickly.

Figure 9. This at-capacity site receives rooftop runoff from adjacent townhomes.

Storm water strategies

Areas that are at capacity are prime locations for incorporating storm water forestry practices (SFPs), such as the forested filter strip. SFPs are storm water treatment practices that have been modified to incorporate trees into the design, Therefore, if they will not conflict with the intended use of the site, trees planted can be part of a practice design. The forested filter strip incorporates a small depression and berm to temporarily pond water and allow it to enter the forested area slowly without causing erosion. Figures 10 and 11 illustrate the forested filter strip, and Part 2 of this manual series provides guidance on its design.

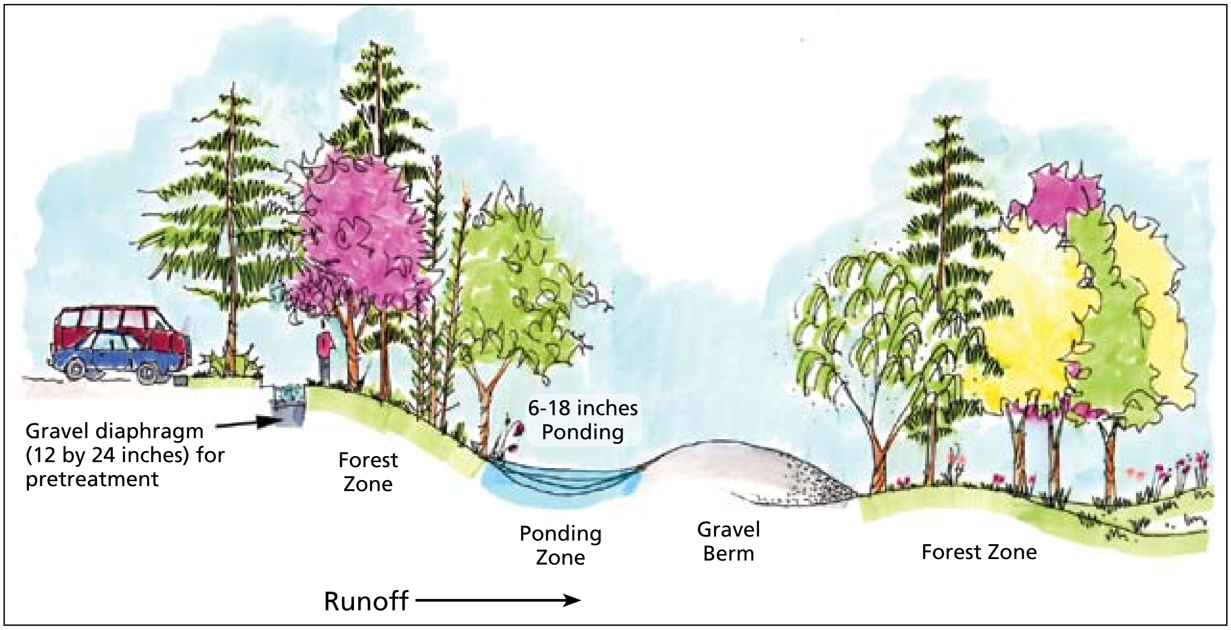

Figure 10. Forested filter strip profile shows how runoff flows through the various zones.

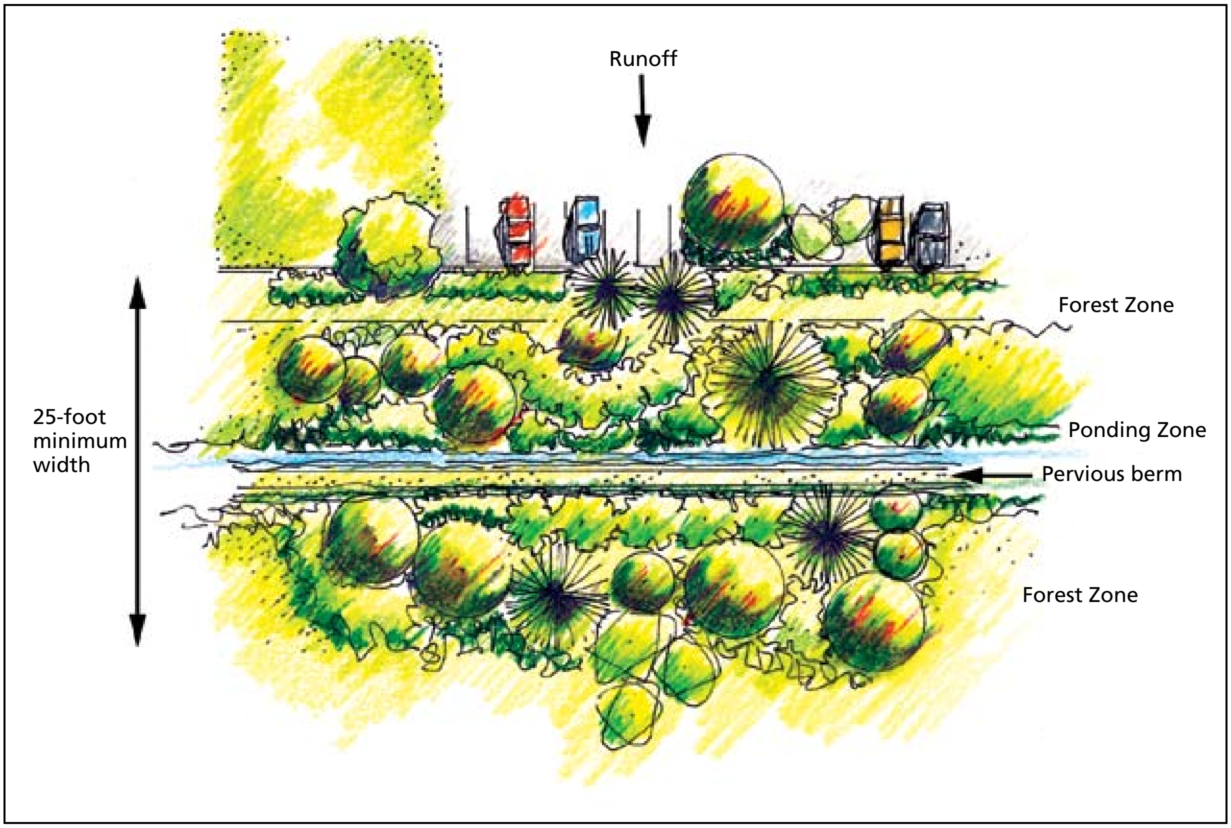

Figure 11. Forested filter strip plan view shows its suitability to a linear area.

Planting strategies

Where storm water strategies are not pursued, the planting strategy is to use trees to treat storm water runoff, taking into account the volume of storm water runoff at the site when selecting tree species. Storm water runoff provides a source of irrigation for newly planted trees and, if maintained as sheetflow, will not erode new plantings. The species planted should be tolerant of occasional inundation. See Appendix B, Chart 1, for flood tolerance of tree species. Depending on the volume of runoff and the soil drainage, planting strategies may also include providing positive surface drainage away from the tree, mounding the planting soil so that the root ball is partially above grade, or installing subsurface drain lines to remove excess water (Urban, 1992).

Over-Capacity Sites

Over-capacity sites receive shallow concentrated flow, or runoff from an upslope drainage area, or both (Figure 12). Over-capacity sites typically have some potential for treating storm water runoff at their perimeter. Runoff from adjacent land travels over impervious surfaces longer than 75 feet or over pervious surfaces longer than 150 feet, or runoff from an upstream drainage area is directed to the planting area in a storm water outfall.

Identifying over-capacity sites

Over-capacity sites typically show evidence of shallow concentrated flow. Common indicators include rills, gullies, erosion, and sediment deposition at the perimeter of or within the site. Contributing flow lengths are greater than 75 feet (impervious) or 150 feet (pervious), and there may also be an upslope drainage area that outfalls to the site.

Figure 12. Concentrated flow at this over-capacity site must be dealt with before planting.

Storm water strategies

The perimeter of an over-capacity site may be an ideal location to install a storm water treatment practice. Bioretention or filter strips are two possible options for sites where the maximum runoff velocity is 4 to 5 feet per second for a 2-year storm (Claytor and Schueler, 1996). Figure 13 illustrates a bioretention facility that incorporates trees into the design. Part 2 of this manual series, and Claytor and Schueler (1996) provide design guidance for bioretention facilities.

At sites with runoff velocity greater than 1 foot per second, concentrated flow may already have begun to erode the channel. In these cases, the channel should be stabilized using bioengineering techniques, up to the 10-year storm flow height. If channel stabilization is not sufficient, piping the flow may be the only option to eliminate gullies and erosion in the planting area. Over-capacity sites with erosion problems should be corrected before planting trees. See Schueler and Brown (2004) for more information on using bioengineering techniques.

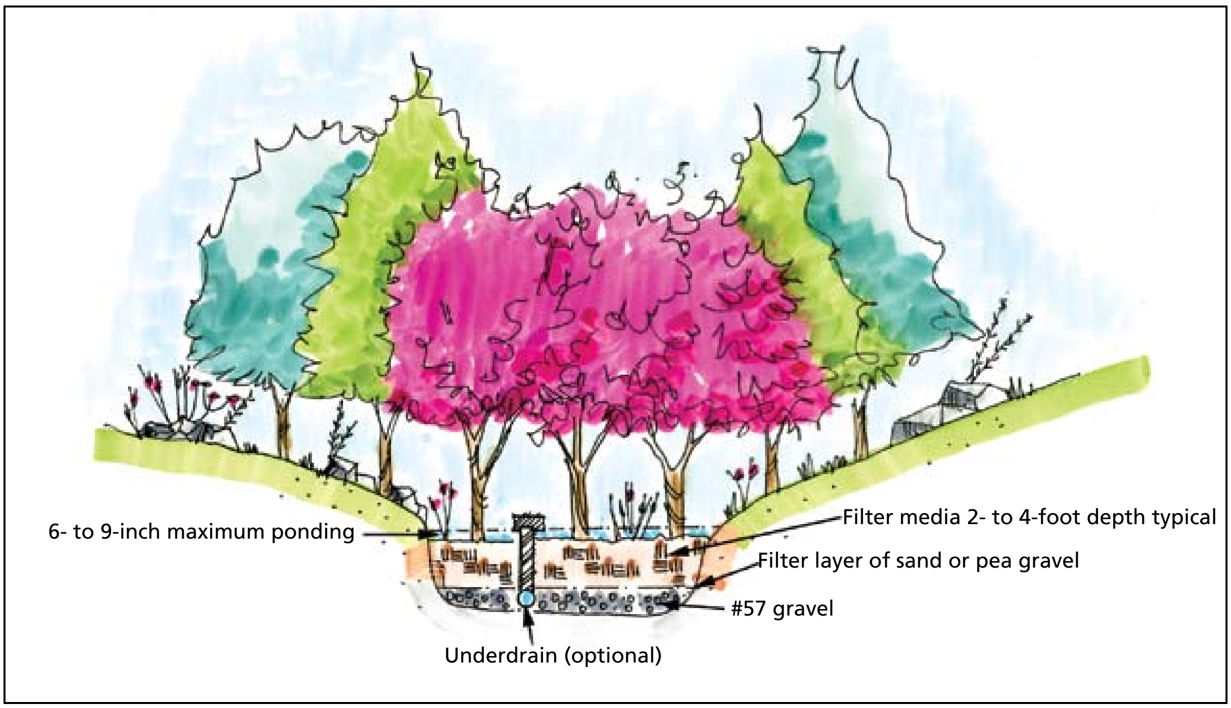

Figure 13. A bioretention facility with trees removes pollutants from storm water runoff.

Planting strategies
Since trees in over-capacity sites may be subject to high flows and erosion, larger stock that is tolerant of occasional inundation should be planted (see Appendix B, Chart 1, for flood tolerance of tree species). Depending on the volume of runoff and the soil drainage, planting strategies may also include providing positive surface drainage away from the tree, mounding the planting soil so that the root ball is partially above grade, or installing subsurface drain lines to remove excess water (Urban, 1992). Sites that have extreme runoff volumes may not be suitable for planting unless storm water is diverted to manage excess flows.

Reducing Conflicts Between Trees and Infrastructure

The built nature of the urban landscape presents unique challenges to maintaining and expanding tree cover while minimizing damage to adjacent infrastructure, such as pavement, structures, and utilities (Figure 14). The municipal costs to repair infrastructure damaged by trees can be high. The annual cost of repairing sidewalk and road damage by trees is estimated at more than $42 million in California alone (Dodge and Geiger, 2001). Where trees and infrastructure conflict, the offending trees are often removed or pruned to the point where they no longer provide their intended benefits. The unique quality of the urban forest is its coexistence with the built environment. Planting the right tree in the right place, and using specific design and construction techniques can reduce these conflicts and allow substantial tree canopy to thrive in the urban landscape. It is important to consider and, if necessary, make changes in these areas:

- Species selection
- Site design and layout
- Construction materials
- Maintenance strategies

Preplanning that incorporates these types of changes can prevent tree-infrastructure conflicts in new developments or can remedy existing conflicts when used in a retrofit. Changing the way sites are built early in the design process can reduce damage to both infrastructure and trees, and integrate trees into the urban landscape to provide maximum benefits. Part 2 of this manual series provides information on incorporating trees into development sites. Table 9 indicates which strategies apply to the five major types of infrastructure discussed in this chapter: utilities, pavement, structures, lighting and signs, and trails. Strategies for each type of infrastructure are discussed below.

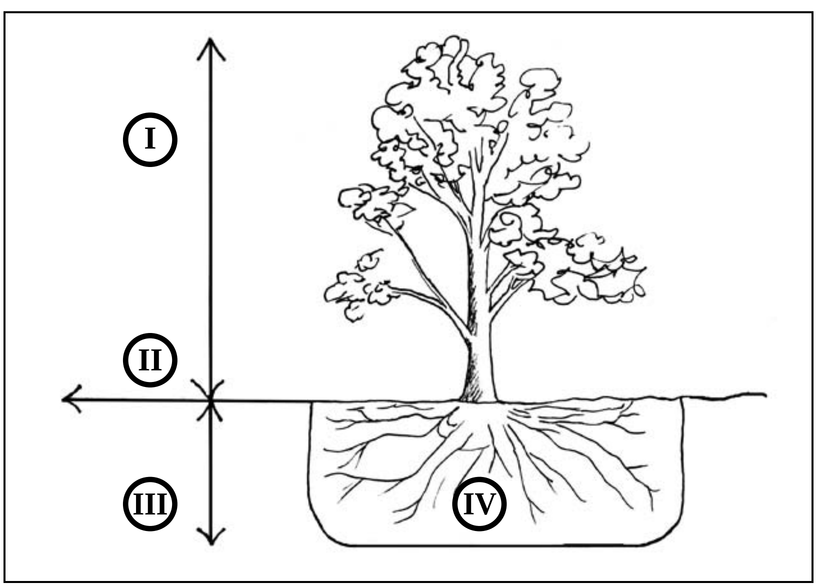

Figure 14. Trees may conflict with infrastructure (I) above ground, (II) at the surface, (III) below ground, or (IV) in the root zone.

Table 9. Methods That Reduce Conflicts Between Trees and Infrastructure				
Type of Infrastructure	**Method**			
	Tree Species Selection	**Site Design and Layout**	**Construction Materials**	**Tree or Utility Maintenance**
Utilities	X	X	X	X
Pavement	X	X	X	X
Structures	X	X	X	X
Lighting and signs	X			
Trails	X	X		

Utilities

Utilities include overhead wires and underground utilities. Overhead wires are normally confined to electric, telephone, or cable, while underground utilities can also include water, sewer, or gas lines. Methods to reduce conflicts for overhead wires and underground utilities are discussed below.

Overhead wires

Overhead wires having the most potential for conflict with trees are high voltage electric lines. When trees planted directly underneath these lines grow to maturity, they can lead to brief or sustained power outages, downed wires, or other safety hazards (PSU, 1997). Utility companies regularly prune trees growing near high voltage power lines to ensure safety and minimize service disruptions. The recommended clearance between trees and wires varies according to voltage; check with the local utility company to locate high voltage wires and identify clearance standards. High voltage wires are often those placed highest on the power pole.

The best way to avoid conflicts between trees and overhead wires is to install utilities underground. Many communities are already doing this, while others are in the process of changing their local codes to allow the placement of utilities under street rights-of-way. This method usually applies only to new developments, because of the cost involved, but could be applied in a retrofit where utility wires needed to be upgraded anyway. If utilities cannot be placed underground, they can be located on only one side of the street. Small trees can be planted underneath the wires (using appropriate species and setbacks), and large trees can be planted on the other side of the street.

When trees are planted near overhead wires, appropriate species and setbacks should be used. Some commonly recommended setbacks and maximum tree heights when planting near overhead wires are presented in Table 10. These setbacks are general guidance only and do not necessarily apply in every situation. Local utility companies can provide additional guidance on the location of high voltage wires and recommended overhead clearance between trees and these wires. Another consideration is that in space-limited urban areas, it may not be possible to adhere to these setbacks and still find room to plant trees (especially large ones). To accommodate trees, these setbacks can be reduced with the knowledge that trees planted near high voltage wires will require regular pruning and species should be selected accordingly. For example, tree species with a large, coarse, horizontal branching structure (e.g., London plane or red oak) can be pruned extensively, unlike species with a pyramidal growth form or those known to be structurally unstable, such as Bradford pear (Figure 15).

Table 10. Recommended Minimum Setbacks for Overhead Wires		
Recommended Setback	**Description**	**Source**
10-15 feet*	Height setback between top of mature tree and overhead wires	Gilman, 1997; Head and others, 2001
10 feet	Distance setback for small trees (< 30 ft)	GFC, 2002; Gilman, 1997
15 -20 feet	Distance setback for medium trees (30-50 ft)	PSU, 1997; Head and others 2001
20 to 40 feet	Distance setback for large trees (> 50 ft)	Nebraska Forest Service, 2004; Head and others 2001
20 feet	Distance setback from transmission right-of-way for all trees taller than 15 feet	Kochanoff, 2002

*Based on the typical height of overhead wires (25 to 45 feet), trees planted under utilities should be 15-30 feet tall when mature, to maintain this height setback (City of Chicago, no date; City of Seattle, no date; Kochanoff, 2002; PSU, 1997)

Figure 15. Bradford pear trees are not well suited to extensive pruning to reduce conflict with overhead wires.

Finally, maintenance strategies can be used to reduce conflict between trees and overhead wires. This includes pruning methods that minimize damage to trees. Directional pruning is the arboriculturally preferred pruning method and is now used by most utilities (PSU, 1997). With directional pruning, branches growing towards wires are removed back to the parent branch or trunk. By removing the branch at a point where it would shed naturally if the branch died from natural causes, future growth is directed away from wires.

Underground utilities

Underground utilities, such as water, sewer, electric, and gas lines generally do not cause conflicts with trees, with a few exceptions. First, for safety reasons, tree planting is not recommended near underground utilities to reduce the possibility of hitting gas or sewer lines. A 10-foot setback is recommended to create a safe buffer to underground lines (GFC, 2002; Gilman, 1997; Head and others, 2001).

Next, tree roots can cause sewer and water pipes to clog because the roots naturally seek out water and may enter the pipes through small cracks or weeping joints. It is rare for roots to cause structural failure of sewer pipes, as structural failure is most often due to inadequate construction (Randrup and others, 2001). Interference between trees and sewer systems is most likely to occur with older or deteriorating systems (Randrup and others, 2001). Use of appropriate construction materials and methods can prevent this deterioration, but little can be done for failing existing systems short of costly upgrades. A more cost-efficient approach used by homeowners is to periodically clean out the pipes using a sewer-drain cleaning service.

Conflicts may also arise when installation, repair, or maintenance of underground utilities leads to damage of nearby trees. Maintenance strategies that do the least amount of damage to nearby trees should be chosen. Tunneling is a useful alternative to other methods, such as trenching or root pruning (Costello and Jones, 2003). Tunneling uses pneumatic excavation tools or hydro-excavation techniques to remove soil under and around roots to create opening for pipes and cables (Costello and Jones, 2003). In bypassing roots, tunneling is thought to have a minimal effect on tree health and structure.

Finally, tree roots can impact perforated pipes used for drainage in storm water treatment practices and other areas. These pipes may become clogged with roots from nearby trees, since tree roots tend to grow towards a water source. Where feasible, a 15- to 25-foot setback between trees and perforated pipes is suggested to reduce this conflict (MDE, 2000; Shaw and Schmidt, 2003).

Pavement

Trees can cause damage to pavement when tree roots grow under the pavement, causing lifting and cracking (Figure 16). Damage to sidewalks is especially common along narrow planting strips between sidewalks and streets (called tree lawns). Inadequate setbacks between trees and pavement are a common cause of damage to pavement; however, other factors that contribute include the quality of the soil and the sidewalk material. Asphalt sidewalks had significantly more conflicts with roots than did concrete sidewalks (Wong and others 1988). The potential for sidewalk damage increased where planting soils were compacted, because roots tend to grow along the surface in search of water and oxygen (City of Saint Louis 2002, Day 1991). Once tree roots cause damage, reducing or correcting the damage can harm the tree; or the tree may be removed completely in order to correct the problem.

Traditional street tree plantings emphasize individual tree pits in which tree roots are confined, creating potential for damage to nearby sidewalks as roots seek out water and oxygen. To reduce conflict between trees and pavement, appropriate species selection and changes to site designs and layouts, and construction materials may be used. Most of these alternatives apply to sidewalks. Each is discussed below.

Species selection should be a consideration when planting trees near pavement. Tree species with large trunk flare or root buttress characteristics are not good choices to plant in small tree lawns (Costello and Jones, 2003). Appropriate species for these spaces should be chosen based on the trunk diameter at ground level (DGL), which accounts for the trunk flare, root buttress, and trunk diameter. To avoid conflict, the DGL of species to be planted should be significantly less than the size of the planting space (Costello and Jones, 2003). Costello and Jones (2003) provide guidance on determining DGL values for local species.

Figure 16. Tree roots cause adjacent pavement to crack.

Alternative site designs ensure that trees have an adequate volume of good soil, water, and oxygen available so that roots are discouraged from growing near the surface. Redesign is generally feasible only for new developments but could be applied as a retrofit where sidewalk renovation is planned in conjunction with relocation or repair of underground utilities. Box 3 presents some examples of alternative sidewalk design methods for reducing tree conflicts. Figure 17 illustrates one of these methods, a curving sidewalk. The goal of alternative sidewalk designs is to provide enough soil rooting volume through larger planting space or shared rooting volume so that tree roots do not need to grow underneath the sidewalk.

BOX 3. ALTERNATIVE SIDEWALK DESIGN METHODS

- Larger planting space
- Curving sidewalk
- Pop-outs
- Nonstandard slab sizes
- Monolithic sidewalks
- Increased right-of-way
- Tree islands
- Narrower streets
- Bridging
- Lower planting sites
- Modified gravel layer
- Sidewalk elimination

Source: Costello and Jones (2003)

Figure 17. A curving sidewalk allows space for street trees.

Another element of site design that can be changed to reduce tree-sidewalk conflicts is to increase setbacks between trees and pavement. Most forestry guidance on the subject recommends a minimum setback of 10 to 15 feet (GFC, 2002; Francis and others, 1996; City of Saint Louis, 2002). This is supported by a study that found damage to sidewalk was most likely to occur when setbacks were less than 10 feet (Randrup and others, 2001). While these setbacks can greatly reduce potential for damage to sidewalks, if they are strictly adhered to in urban areas, there may not be adequate space for planting large trees. If use of these setbacks would eliminate trees entirely, designers should pursue alternative site layouts and construction materials to ensure that trees are integrated into urban areas, where their benefits are most needed.

Construction materials that can be used to reduce tree-sidewalk conflicts can be grouped into alternative sidewalk construction materials and materials used in the tree root zone (Box 4).

Alternative sidewalk materials include strategies to strengthen concrete or concrete alternatives. Concrete is strengthened by reinforcing with rebar, mesh, fiber, or an alternative fiberglass-reinforced plastic rebar. Alternatives to concrete include asphalt, which may not reduce damage but is more easily replaced than concrete; permeable concrete or brick pavers, which will lift individually rather than as an entire slab of concrete; and rubber sidewalks, which are flexible and can expand with the tree roots. One limitation of flexible pavements is they do not work well with compacted soils. The goal of alternative sidewalk materials is to allow tree roots to grow underneath the sidewalk while preventing sidewalk damage. Costello and Jones (2003) provide additional information on alternative sidewalk materials.

BOX 4. ALTERNATIVE CONSTRUCTION MATERIALS TO REDUCE TREE-SIDEWALK CONFLICTS

Alternative Sidewalk Materials

- Reinforced slab
- Thicker slab
- Expansion joints
- Pervious concrete
- Asphalt
- Decomposed granite and compacted gravel
- Permeable pavers
- Recycled rubber
- Mulch
- Grind edge
- Ramps or wedges
- Mudjacking

Materials Used in Root Zone

- Root barriers
- Continuous trenches
- Root paths
- Structural soil
- Root channels
- Foam underlay
- Steel plates

Source: Costello and Jones (2003)

Materials used in the tree root zone to reduce tree-sidewalk conflicts include root guidance systems and structural soils. Root guidance systems are designed to direct root growth away from infrastructure. Methods used range from barriers or plates that restrict root growth either laterally or radially, to underground trenches, paths, and channels, through which roots are directed to appropriate areas. The success of root guidance systems has been variable. They apparently are most effective in situations where tree-infrastructure conflicts are not a major concern, for example, on sites with uncompacted soils or sufficient planting area (Gilman, 1997; Harris and others, 2004). Experts caution against using root guidance systems to force the tree to stay within a confined planting space; roots will generally find their way around these barriers if needed. Most root guidance systems must be installed at the time of planting or sidewalk construction and are not suited for a retrofit. Consult Costello and Jones (2003) for a detailed review of root guidance systems.

Structural soils are engineered soils that provide a suitable medium for plant growth while also meeting hardscape engineering requirements. Structural soils are used to replace existing site soils that are not suitable for planting, and they increase rooting space and reduce infrastructure damage at sites where alternative sidewalk designs are not feasible. Structural soils are sold under various brand names, including CU Soil, developed by Cornell University's Urban Horticulture Institute, Carolina Stalite, and Amsterdam Tree Soil, which has been successfully used in tree pits in the city of Amsterdam in the Netherlands. Costello and Jones (2003), Grabosky and others (1999), and Couenburg (1994) provide some additional information about these specific types of structural soils.

The most common application of structural soils is for street tree plantings, as they can be used under pavements that bear light loads, such as sidewalks. Structural soil allows root growth to occur underneath pavement so that roots can grow outside of the tree pit. As a result, tree roots have access to a continuous soil trench that runs underneath the sidewalk and connects to the planting pits. Figure 18 illustrates a typical application of structural soils within a linear street tree design.

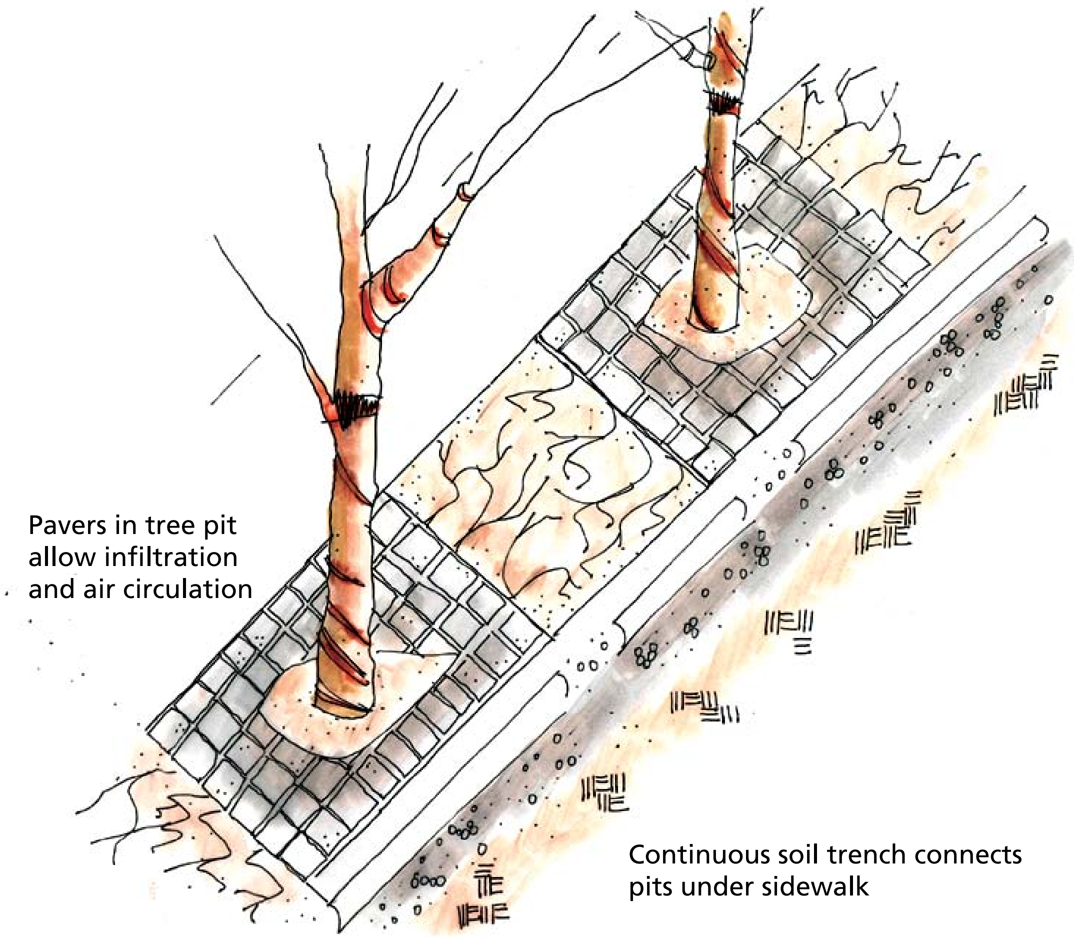

Figure 18. Structural soils used in a street tree application increase rooting space.

Structures

Trees planted next to structures may not have enough room for proper root development and are subject to increased heat load reflected off building surfaces. If trees have aggressive roots, they have the potential to undermine the building foundation. Additional damage to the building may be caused by falling branches or the tree toppling over due to one-sided root growth. Because of these potential conflicts, recommended setbacks between trees and structures range from 15 feet for small trees (trees under 30 feet high when mature) and 20-25 feet for large trees (trees over 50 feet high when mature) (GFC, 2002; Nebraska Forest Service, 2004). In arid regions or other areas where fire is a concern, a larger setback is often required to provide a firebreak. For example, clearing of vegetation is often required within 100 feet of homes in California (Cochran, 1997).

These setbacks are guidelines only and can be reduced to allow planting of trees that shade buildings and intercept rainfall, provided adequate soil volume is present (Figure 19). If this method is pursued, the tree's lower branches must be pruned to allow the trees to grow over the structure. A rule of thumb regarding pruning is to maintain two-thirds of the tree height as crown.

Figure 19. Trees planted in a narrow strip between structures may not get enough light or soil.

Lighting and Signs

To prevent trees from blocking lights and signs in urban areas, appropriate setbacks and species selection are important. Trowbridge and Bassuk (2004) recommend allowing a distance setback of 10 feet between trees and lighting, and increasing this distance for large trees (over 50 feet high at maturity). Species should be selected that are the appropriate size for planting near lighting and signs. Tall trees work best near lights; the mature tree height should be such that the canopy will grow above the light and will not prevent light from reaching the ground (Gilman, 1997). For signs, choose small trees near tall signs and near lower signs, plant large stock with high branches.

Trails

Urban greenways and trails provide an opportunity for recreation, and trees can enhance this experience. However, safety can be a concern when trees are planted near trails and reduce visibility. To ensure safety near trails, a setback should be provided between trails and trees or shrubs. Flink and Searns (1993) recommend a setback of 10 feet between the centerline of the trail and trees or shrubs, and advise planting only low-growing herbaceous vegetation within this setback. Additionally, they suggest limiting the use of evergreens and trees with drooping limbs near trails and trail approaches, seating areas, and intersections. Palone and Todd (1998) recommend regular pruning and vegetation maintenance in these same areas to maintain visibility; for example, prune existing trees so limbs do not extend below 8 feet from the ground.

Protecting Trees from Animal and Human Impacts

Potential human and animal impacts should be considered when developing a planting plan to protect trees from impacts. The URSA helps determine if any protection measures are needed. Animals such as deer and beavers can impact newly planted trees through browsing and gnawing. These animal impacts are often compounded in suburban areas, since few natural predators exist, hunting is restricted, and remaining habitat is limited. Human impacts can include damage to trees from heavy pedestrian traffic, automobiles, lawnmowers, and vandals, to name a few. Methods to protect trees from beavers, deer, and human impacts are described below. In addition, installing signs, fencing, flagging, or a combination of these, can be useful at any planting site in letting the public know about the reforestation project, and to protect the trees from impacts.

Beavers

Beavers can cause damage to existing trees in riparian areas by flooding from beaver dams or to new trees by removal of tree bark (Kwon, 1996). Some solutions for dealing with beavers include these:

- Deer repellent, which has an unpleasant odor and will drive beavers away
- Water level control devices where a pipe is installed under the dam, and the water is drained
- Live-trapping and physical relocation of beaver
- Tree guards, which are 3-foot collars made of heavy cloth or wire mesh, installed around the base of each newly planted tree

Local regulations may restrict beaver relocation or water level control devices. Tree guards can be cost prohibitive on a large or densely planted site. For additional information on methods to protect trees from beaver damage, see CT DEP (2000), Jensen and others (1999), Kwon (1996), and LeBlanc (1997).

Deer

Excessive deer browsing damages existing shrubs, prevents regeneration of trees and shrubs, and is one of the primary ways that plants are damaged, in both residential and natural areas (Turner, 1998). Deer feed on the young leaves of understory plants, seedlings, and seeds, which may make reforestation plans and buffer establishment more difficult. Forests that are heavily impacted by deer may have a sparse understory, a distinct browse line up to a height of 5 feet, and little regeneration of new trees and shrubs. If forested sites adjacent to the planting area show indications that deer are present, appropriate precautions should be taken to protect planted trees.

Methods to reduce damage to trees from deer in urban areas include repellents, fencing, and tree shelters. Additional options include selecting and planting species that are unpalatable to deer, and planting larger stock so that the crown of the tree is above the browsing height of deer (PERT, no date). Listings of tree and shrub species that generally are not preferred by deer are provided at these Web sites:

- Maryland Department of Natural Resources. Less palatable landscape plants. www.dnr.state.md.us/wildlife/ddmtplants.asp

- Rutgers Cooperative Research and Extension. Landscape Plants Rated by Deer Resistance. www.rce.rutgers.edu/deerresistance/default.asp
- University of Minnesota Extension Service. Coping with Deer in Home Landscapes. www.extension.umn.edu/projects/yardandgarden/ygbriefs/h462deer-coping.html

Typically some combination of these methods is most effective, since deer are adaptable and may find a way around any one particular method. Deer control methods are described below.

Figure 20. Tree shelters can be installed to protect seedlings at a reforestation site.

Tree shelters are plastic tubes that enclose the lower portion of the tree and protect trees against browsing by deer and rubbing by bucks. Tree shelters also retain moisture and reduce weed competition, and are generally the most cost-effective method for protecting trees from deer. To protect seedlings from deer, shelters should be 4 feet high. Chapter 6 provides more detail on tree shelters, and Figure 20 illustrates tree shelters installed to protect seedlings at a planting site.

Deer repellent is a malodorous substance that drives deer away, and commercially available products include in-soil systemic tablets and foliar sprays. Systemic repellent tablets are most effective at moderate deer densities while foliar sprays work best for short term (8-12 weeks) protection from browsing (Hairston-Strang, 2005). Lemieux and Maynard (1999) recommend using a repellent that both tastes and smells bad to combat feeding when deer are hungry enough to tolerate the smell. See Tregoning and Kays (2003) for more information on the effectiveness of various deer repellents.

Fencing can be used to exclude deer from a planting area (Figure 21). Deer fencing should be 8- to 10-feet high and can be electric, wire, or wire and plastic (Hairston-Strang, 2005). This method can be very effective, but is also expensive and requires some maintenance to repair damage. A more cost-effective option is to plant new trees in clusters and fence them in (Hairston-Strang, 2005).

Figure 21. Deer heavily browse understory vegetation in unprotected forest (right) outside a deer exclosure. (Photo courtesy of Will McWilliams)

Human Impacts

In urban areas, human impacts on newly planted trees can be caused by automobiles, vandals, pedestrian traffic, and mowing. Accidental damage from mowing is most common in tree plantings in former turf areas. The most common injury to curbside trees is from vehicles (Foster, 1978). Damage to trees from vehicles or mowers can open wounds that allow disease to enter. Vandalism may be more common in highly urban areas, and in some sites plants may be "relocated" for personal use. Heavy pedestrian traffic can damage seedlings or cause soils in the planting area to become compacted.

To reduce damage to trees from pedestrian traffic, concrete bollards, posts, fencing, thorny shrubs, or pathways can be installed to direct traffic away from the planting areas (Figure 22). Using mulch also reduces impacts to tree root areas. Use of mulch and tree shelters can reduce potential damage from lawnmowers. Additional information on tree shelters and mulch is provided in Chapter 6. Using appropriate setbacks between street trees and the edge of the curb in areas with on-street parking can reduce damage from cars. In addition, species planted along roadsides should not have thin bark (Gilman, 1997). At planting sites that have high potential for vandalism, installing lighting, tree cages, or benches may protect trees. Palone and Todd (1998) suggest planting large stock and using trees with thorns or inconspicuous bark to discourage vandalism.

Figure 22. Posts were placed between trees planted in a Baltimore vacant lot to discourage pedestrian traffic near trees and to prevent illegal dumping in the lot.

Chapter 5. Site Preparation Techniques

Planting trees in urban areas can greatly improve community character and provide multiple environmental benefits. However, urban sites are often highly disturbed and may need to be prepared for planting by removing trash and other debris, controlling invasive plants, and amending the soil. The Urban Reforestation Site Assessment (URSA) worksheet in Appendix A indicates what level of site preparation is needed for successful reforestation at each planting site.

This chapter describes methods for preparing urban sites for planting.

Trash and Debris Cleanup

Illegal dumping of trash, rubble, and other debris often occurs in isolated or unpoliced urban areas such as riparian corridors or parks, where dumpers dispose of trash for free instead of going through the proper channels and paying required fees (Figure 23). If present, trash and debris should be removed from the site before tree planting. Removing trash and debris not only makes the site more attractive, but it also prevents release of pollutants from the illegally dumped material into local waterways. Site cleanup and subsequent tree planting can often discourage future use of the site as a dumping area.

Figure 23. Trash and debris must be cleaned up as part of preparing a site for planting.

Evaluating the Site

Several types of information are collected during the URSA to determine cleanup needs before planting, as shown in Table 11.

Table 11. Factors to Evaluate at an Illegal Dumping Site	
Information Collected During URSA	**Use in Planning Trash Cleanup**
Location of trash	The location of trash and other illegally dumped material should be noted on the site sketch to make the cleanup efficient.
Volume of trash	Estimated volume of trash in number of pickup truck loads will determine how many staff or volunteers are needed, the number of trash bags or type of equipment needed, and can also be used to estimate cost of disposal.
Type(s) of trash	Recording the types of trash present (e.g., household garbage, appliances, medical waste, construction debris) will help to identify potential safety hazards, determine whether heavy equipment is needed, and identify disposal options (i.e., recycling, landfill, dumpster).
Source of trash	It is important to note the source of trash and debris (if known) in order to develop a plan to address source of trash (i.e., education program, fines, better lighting, dumpster management).
Site access	Identifying parking areas and facilities for volunteers, temporary storage areas for collected trash, and access for heavy equipment or trucks helps to organize the logistics of the cleanup.

Planning and Implementing the Cleanup

Depending on the volume and type of trash dumped at the site, the project can be implemented by municipal staff or by volunteers from the community led by a local watershed group and supported by municipal agencies. Trash cleanup projects are ideal for watershed and other volunteer groups because almost anyone can participate, and they are effective means to educate volunteers and increase community awareness about watershed restoration. If volunteers are used, they should be recruited well in advance of the cleanup day. Recruitment of volunteers may include posting flyers at community locations or on Web sites, or direct recruiting through a watershed organization, school or church group, neighborhood association, or other organization. Organizers should notify local newspapers, radio, and television about the cleanup, with an emphasis on progress made, the watershed restoration effort, and recognition of volunteers.

Whether the cleanup is done using volunteers or municipal staff, safety is an essential responsibility for the cleanup organizer, and potential risks should be thoroughly evaluated. In addition, arrangements for removing trash and debris should be made in advance with the local public works department. It may be helpful to coordinate with local recycling centers on how to recycle materials collected during the cleanup (plastics, aluminum, glass). If hazardous, toxic, or medical waste is present at the site, a local hazardous materials team or emergency crew may be needed to clean up the site and determine if it is necessary to remediate the site. Typical supplies needed for a site cleanup include but are not limited to these: liability waiver forms, waders, orange safety vests, protective gloves, emergency contact numbers, first aid kits, refreshments, trash pickup tools, wheelbarrows, trash bags, heavy equipment (such as a loader) for transporting larger materials, and a pickup truck or dump truck (rental if necessary) for disposal.

Cleanups are typically done in a single day. Cleanup typically begins at the farthest point and volunteers are broken into groups to clean designated areas of the site. All trash and debris collected during this period should be organized into piles of recyclables (such as plastic, glass, aluminum, and yard waste) and nonrecyclable garbage. Municipal recycling and trash removal agencies should coordinate trash hauling. It is helpful to track the amount and type of garbage collected during the cleanup.

An important followup to removing trash and debris from a planting site is to take action to ensure that illegal dumping does not continue to be a problem at the site. Depending on the source of the problem, the following methods may be used to discourage dumping:

- Placing locks on dumpsters
- Constructing dumpster shelters
- Installing *No Dumping* signs
- Fencing vacant lots
- Limiting vehicle access to the site
- Installing better lighting
- Conducting watershed education
- Citizen monitoring (particularly if the site is part of a stream reach)

Costs of Trash and Debris Cleanup

The overall cost of a stream cleanup is highly dependent on the amount of donated supplies and services. Trash and debris hauling and landfill disposal fees can be significant—costs range from $76 to $225 per ton, depending on the type of trash and responsible party (PEL, 1995). Donation of services, corporate sponsors, waiving of fees, and the use of publicly owned equipment can reduce some of the cleanup costs. Most cleanups use volunteer labor, but organizers must supply equipment, such as hand tools, waders, and safety equipment (e.g., gloves, goggles). Efforts should be made to obtain these materials as donations or at a reduced cost. Additional costs include volunteer appreciation materials, refreshments for volunteers, promotional materials, and educational materials.

Invasive Plant Control

Invasive plant species are generally defined as plants that out-compete and replace more desirable native species due to their aggressive growth patterns. Although both native and nonnative plants can be invasive, the majority of invasive plants are nonnative species. Invasive plants are commonly found in disturbed landscapes such as urban areas, agricultural areas, stream corridors, and roadsides, and are often unintended escapees from nearby landscaped areas. Invasive plants are able to become dominant because they typically have many of the following characteristics (Haber, 1997):

- Grow rapidly
- Grow under a wide range of climate and soil conditions

- Produce abundant seeds
- Have adaptations that promote easy dispersal
- Have seeds that stay viable for many years in soil
- Have adaptations, such as bad taste or odor, that reduce herbivory by larger animals
- Lack insect pests or pathogens to keep them under control in a new ecosystem

Evaluating the Site

Invasive plants that will limit the survival of newly planted trees should be removed before planting, and must be monitored and controlled after planting to encourage the establishment of new trees. The density and extent of invasive plant species present at a planting site are recorded during the URSA. If desired, a more detailed survey of invasive plants can be completed for the planting site, as described in Galli and others (2003).

Identification of invasive plants requires local knowledge of invasive plant species and identification skills. Some examples of invasive plants commonly found in the northeastern United States include oriental bittersweet, purple loosestrife, Japanese knotweed, porcelainberry, Canada thistle, multiflora rose, kudzu, mile-a-minute weed, garlic mustard, phragmites, tree-of-heaven, Japanese honeysuckle, and English ivy (Figure 24). State native plant societies, regional exotic pest plant councils, and state invasive species councils are good sources of information on invasive plant species, as are Huebner and others (2004) for the northeast United States, Miller (2003) for the southern United States, USDA NRCS (2006), and National Invasive Species Council (2003).

Figure 24. Tree-of-heaven (left) and English ivy (right) are common invasive plants in many urban areas of the United States.

Table 12 presents an indexing system developed by the Metropolitan Washington Council of Governments to rank the level of invasive species infestation based on the percent coverage of invasive plants at a particular site.

Table 12. Invasive Plant Indexing System	
Invasive Plant Coverage (Percent per acre)	**Ranking**
0 – 10	None – Very Light
10 – 25	Light
25 – 50	Moderate
> 50	High

Source: Galli and others (2003)

Galli and others (2003) recommend control of invasive plants if the ranking is light to high. However, complete eradication of invasive species may not be practical if coverage is high, populations are well-established, adjacent properties are overrun, or invasive species are deep-rooted (May, 2001; National Invasive Species Council, 2003). A more realistic goal at these sites may be to manage the unwanted vegetation each year to keep its growth in check. It may also be too expensive and difficult to control each of the many nonnative and invasive species present at some urban sites. A more reasonable approach is to identify which plants will limit the success of new plantings and focus efforts on control of those species. Adequate control methods may not available for all invasive plant species, and it can take up to 5 years to successfully eradicate invasive species from a site (May, 2001).

Selecting and Implementing Control Methods

Methods to control invasive plants fall into four major categories: physical, chemical, cultural, and biological controls. **Physical methods** of plant control methods include manual removal, mechanical removal, heavy equipment removal, solarization, girdling, and prescribed burning. **Chemical methods** include the use of selective herbicides to kill unwanted vegetation. **Cultural control** involves the modification of human behavior both within and around the natural area. **Biological control** uses a plant's natural enemies to control the species population. Methods to remove and control invasive species are generally selected based on the species characteristics (e.g., perennial or annual, method of propagation), level of infestation, site characteristics, and budget and time constraints (Haber, 1997; May 2001; PERT, no date). Table 13 provides a comparison of each method, followed by additional detail on implementation. Generally, the most applicable methods for urban areas are manual, mechanical, chemical, and cultural methods.

Table 13. Comparison of Invasive Plant Control Methods				
Method		**Advantages**	**Disadvantages**	**Applicability**
Physical	Manual	• Inexpensive • Has little ecological impact	• Labor intensive	• Works for annuals or taprooted plants • Best used on small areas
	Mechanical – Mowing	• Simple to add to regular maintenance program	• Requires repeated applications	• Works for annuals • May be combined with other methods • Requires adequate space for mowing between plants
	Mechanical – Heavy Equipment	• Removes roots effectively	• Creates land disturbance • More expensive than chemical methods	• Best used on densely infested sites with no native vegetation or sensitive resources to protect • Best used for initial removal only
	Solarization	• Inexpensive • Low labor • Has little ecological impact	• Cannot re-plant for up to 2 years • May leave site susceptible to further invasions	• Works for winter annual weeds that germinate under cool conditions • Best used in summer • Best used for initial removal only
	Girdling	• Has little ecological impact • Remaining tree • provides habitat • Inexpensive	• Limited species applicability • Requires at least 1 year to be effective • Creates safety hazard	• Applies to trees only • Works on pines, some oaks and some maples (typically not invasive)
	Burning	• Kills plant roots and stems, may kill seeds • Fire is a natural and desirable process in many ecosystems	• May release weeds • Can be hazardous • Requires permit or is restricted in urban areas	• May be used in combination with herbicides • Applicable in less populated areas
Chemical		• Does not create land disturbance • Less costly than mechanical controls • Kills plant roots and stems	• May have toxic effects if not used properly • Can be labor intensive • Repeat application may be required	• Should be used in concert with mechanical controls such as mowing • Works on most annuals and perennials
Cultural		• Several methods provide additional benefits (e.g., crops, shade, habitat) • Has little ecological impact	• Can be labor-intensive	• Mainly used for long-term control or spread prevention
Biological		• Has little ecological impact • Cost-efficient	• Does not eradicate species but provides some control	• Applicable at regional scale • Only works for species with specialized natural enemies

Manual methods

Manual plant control includes using a shovel, machete, or loppers to carefully remove plants by hand. As much of the root as possible should be removed and care should be taken not to cause erosion or compact the soil.

Mechanical methods

Mechanical plant removal includes using a mower, chain saw, or weed whip to remove plants (Figure 25). Mowing is most commonly used and reduces seed production and restricts weed growth (Tu and others, 2001). The mower blade should be set high enough to cut the weeds but not the desired vegetation (May, 2001). Cut fragments should be collected if species are capable of re-sprouting from stem or root fragments (Tu and others, 2001).

Figure 25. A weed whip may be helpful in removing invasive species.

Heavy equipment

Mechanical plant removal with heavy equipment includes using a bulldozer, backhoe, or loader to remove plants in areas where invasive plant density is high, native species are absent, and impacts to sensitive natural resources are negligible (RNSP, 2002). This method should be followed immediately by tree planting, and requires proper erosion and sediment control practices.

Solarization

Solarization (also called smothering) involves covering the soil with a sheet of black or clear plastic (polyethelyne film) to increase soil temperature and block sunlight to kill plants (Tu and others, 2001). Solarization is used for weeds whose seeds are sensitive to temperature changes. This method may cause significant biological, physical, or chemical soil changes that will prevent new plant growth for up to 2 years (Tu and others, 2001).

Girdling

Girdling involves use of a knife, axe, or saw to cut away a strip of bark several centimeters wide around a tree trunk, which kills the tree. The cut should be deep enough to remove the inner bark, which is needed for transport of food through the plant, but not so deep as to topple the tree (Tu and others, 2001). The remaining dead tree can provide habitat for nesting birds if it does not pose a safety hazard. This technique is used only on species that do not resprout in response to girdling (Tu and others, 2001).

Prescribed burning

Fire consumes above-ground vegetation and may kill seeds or break the dormancy of seeds, allowing later removal of plants (RNSP, 2002). Fire affects the composition of native plants and may support its natural resistance to invasives (RNSP, 2002). Prescribed burns may include large-scale burns or spot-burning; however, both require a permit. The weather, topography, and available fuel will determine the temperature and intensity of the prescribed burn, and the burn is most effective if done just before flowering or seed set, or at the young seedling or sapling stage (Tu, and others, 2001).

Chemical

With chemical methods, herbicides are applied manually to the offending plants with a weed wick or wiper, or with a sprayer if no desirable vegetation exists at the site (May, 2001). Use of herbicides in riparian areas should be limited to those formulated for aquatic use, such as those containing glyphosate (Palone and Todd, 1998). A buffer should be provided between the application area and any surface waters, and application should be staged to limit any potential toxic effects (Tu and others, 2001). Herbicides should only be used if mechanical, cultural, and biological means are not acceptable or feasible. Herbicides should be applied only during the growing season by a trained, certified pesticide applicator, in accordance with Integrated Pest Management (IPM) guidelines (RNSP, 2002).

Cultural

Cultural methods are generally used to prevent or minimize the spread of invasives rather than to remove them. Techniques include revegetation, restoring soil conditions that favor native vegetation, cultivation, grazing, crop rotation, mulching, use of tree shelters, and proper disposal and maintenance techniques. Examples of proper disposal and maintenance techniques include cleaning boots, tools, tires, and machinery before leaving the site, to avoid tracking seeds of invasives off-site, and using plant disposal methods that do not contribute further to the spread of the invasive plant (RSNP, 2002).

Biological

Biological controls can include the introduction of an invasive plant's natural enemies, such as insects, fungus, or bacteria, which target the invasive plant and limit growth or reproduction. This method is best used on large established populations, but it does not completely eradicate invasive species. Biological controls typically take about 3 to 8 years to show results, but they have little ecological impact (May, 2001). Biological controls of invasive plants are primarily applied on a regional basis. Additional information about biological control of invasive plants in the eastern United States can be found in Van Driesche and others (2002).

Integrated Vegetation Management

No one method of controlling invasive plants is ideal; rather, a combination of biological, physical, chemical, and cultural methods should be used. This approach is often referred to as Integrated Vegetation Management (IVM). It entails taking a comprehensive look at the available methods, considering their effect on the surrounding environment, and addressing both initial removal and long-term control. A successful invasive species control program also seeks to understand the life cycle of the species involved as well as the effectiveness of each control measure (Palone and Todd, 1998). A long-term plan for the management of invasive plants is also necessary, especially in areas where infestations are severe, and will be most intensive as new native plants establish. Additional guidance on IVM and implementation of specific invasive plant control methods is provided in Tu and others (2001) and MD SHA (no date).

Costs of Invasive Plant Control

The costs of controlling invasive plants can range widely, due to the variety of methods available for control. Examples of costs for commonly used methods are $12 per acre for mowing and $54 per acre for herbicide application (Palone and Todd, 1998). Costs for specific invasive plant removal projects in New York and Rhode Island ranged from $50 to $1,000 per acre (PFWP, 2001a; PFWP, 2001b).

Soil Amendments

Most urban planting sites are highly disturbed and do not provide ideal conditions for tree growth (Figure 26). Progressive cycles of development and redevelopment involve wholesale earthmoving; erosion or removal of topsoil; compaction of subsoils; and the filling of depressions, wetlands, and natural rainfall storage areas. Consequently, urban soils are typically very compacted, which physically impedes root development and suffocates the tree by limiting available oxygen (Coder, 2000; VCE, 2002). Most urban soils have a surface bulk density greater than 1.5 grams/cm^2, while bulk densities around 1.4 to 1.6 grams/cm^2 or greater have been identified as limiting to root growth (Craul, no date; CWP, 2000a; USDA Forest Service, 2005). The quality of most urban soils is also poor and is usually not ideal for plant growth, because most of the soil organic matter is removed along with the topsoil during construction. In addition, the soil pH in urban areas is often elevated from excessive building rubble, which contains calcium.

Figure 26. Soils at urban planting sites are often highly compacted and full of rubble, trash, and other pollutants.

Due to the unique properties of urban soils, most need to be amended before planting, to improve growing conditions and increase tree survival. Soils may be amended across the entire planting site or at individual planting holes if the site is large. Compost has been highly successful for improving urban soils, as it increases organic matter, improves drainage, and adds vital nutrients. Other amendments that can improve soil quality include gypsum, limestone, peat, and sulfur. These amendments are described below.

- *Compost* – Compost is decomposed organic material and has long been used in agricultural applications. Compost has recently become more common in urban and suburban settings and is applied to decrease bulk density, improve water- and nutrient-holding capacity, and increase nutrient levels (CWP, 2000a).

- *Gypsum* – Gypsum is hydrated calcium sulfate and is used to decrease soil salinity by combining with sodium to become a soluble salt. Gypsum also increases calcium and sulfur without affecting pH and enhances the structure of clay soils (Chollak and Rosenfeld, 1998).

- *Limestone* – Limestone decreases soil acidity and comes in two forms: calcareous (adds calcium) or dolomitic (adds magnesium) to the soil (DOD, 1996).

- *Peat* – Peat is undecomposed organic matter that increases organic matter, acidity, and water- and nutrient-holding capacity of the soil without increasing nutrient content (DOD, 1996).

- *Sulfur* – Sulfur comes in two forms: agricultural sulfur or aluminum sulfate and is used to increase soil acidity (DOD, 1996).

Evaluating Urban Soils

Soil compaction, pH, and drainage are evaluated at the planting site during the URSA to determine what, if any, soil amendments are needed. Typically, soils that are moderately to severely compacted, are very alkaline or acidic, or are poorly drained will need to be amended. When a penetrometer is used to evaluate soil compaction, soil amendments are necessary if more than half of the samples from the top 15 inches of soil have readings that exceed 300 pounds per square inch (Duiker, 2002). When soil bulk density is analyzed, bulk density greater than 1.5 grams per cubic centimeter should be amended (CWP, 2000a; Kays, 1985). If desired, more detailed soil quality data can be collected during the USRA, such as organic matter content, nutrient availability and salt content. The addition of compost can improve many of these conditions and is recommended for most urban planting areas.

Table 14 provides guidance on corrective measures based on specific soil characteristic thresholds (Palone and Todd, 1998; Craul, 1993; DOD, 1996; Chollak and Rosenfeld, 1998). Soil improvement is recommended if the moderately impacted threshold is exceeded for a given soil parameter, and is required if soils are severely impacted. Specific thresholds for soil properties may vary with soil types and regions.

Table 14. Recommended Corrective Measures for Urban Soils			
Soil Characteristic	**Moderately Impacted Threshold**	**Severely Impacted Threshold**	**Corrective Measure**
Percent sand	>75	>90	Add compost or peat
Percent kaolinitic clay	>50	>65	Add compost or peat
Percent expandable clay	any	>10	Add gypsum
Percent clay and silt	>50	>75	Add compost or peat
Bulk density of clay (mg/m^3)	<1.4	>1.5	Add compost or peat
Bulk density of loam (mg/m^3)	>1.5	>1.7	Add compost or peat
Aeration porosity (percent large pore volume)	<2	<1	Add compost or peat
Infiltration, percolation, and permeability rates (in/hr)	<0.25	<0.20	Add compost or peat
Depth to bedrock (ft)	<4	<2	Add topsoil
Impermeable layers (ft)	<6	<4	Mix soils
Acidic soils (pH)	<6	<4	Add lime
Alkaline soils (pH)	>7.5	>8.5	Add compost or peat, add sulfur
Cation exchange capacity (meq/100g)	>5	<3	Add compost and/or peat
Potassium (lbs/acre)	<124		Add compost
Phosphorus (lbs/acre)	<44		Add compost
Magnesium	Variable		Add dolomitic limestone or compost if deficient
Calcium	Variable		Add calcareous limestone, gypsum, or compost if deficient
Percent organic matter	<1		Add compost or peat
Soluble salt (ppm)	600	1,000	Add gypsum or sulfur, add compost or peat

Planning and Implementing Soil Amendments

Ideally, application rates for soil amendments should be determined by the current soil properties, the desired soil properties, and the properties of the soil amendment itself. For example, compost from one source may have a much higher nutrient or salt content than another source, so the compost should be tested before application. If soil testing is not possible, a general rule of thumb for compost application is to use a 2:1 ratio of loose soil to compost (Chollak and Rosenfeld, 1998; CWP, 2000b). This rule of thumb is based on a target soil organic matter content of 8 to 13 percent, as well as the typical organic matter content of both compost and urban soils (Chollak and Rosenfeld, 1998; Stenn, 2005).

Application rates for lime, gypsum, and sulfur vary and should be determined by soil test results for pH and macronutrients such as nitrogen, sulfur, potassium, magnesium, and calcium. Unterschuertz (1997) and Muntean (1997) promote adding 50 to 100 pounds of gypsum per 1,000 square feet, at the same time as compost incorporation, to improve the structure of heavy clay soils. Lime applications typically range from 50 to 100 pounds per 1,000 square feet to improve unsuitable alkalinity and nutritional deficiencies (Chollak and Rosenfeld, 1998). Sulfur is required as elemental sulfur, and requirements range from 2 to 5 pounds per 1,000 square feet annually (Stahnke, 2004; Muntean, 1997).

Soil should be amended at individual planting holes to a depth of 2 to 3 feet (Figure 27). Soils deeper than 3 feet are generally not very useful to trees (Urban, 1999). In most cases, it will be cost prohibitive to amend soils across the entire planting area, but this may be feasible at smaller sites. At each planting hole, the soil is excavated and placed on a tarp. Next, the soils and compost are mixed in a large bucket at the appropriate ratio and used to fill in the hole. Since each tree will be planted in a hole that is two to three times the width of the root ball or root mass, it is important to amend the entire width of the planting hole. An equally important step is to hand mix the amended soil into the existing site soil along the sides of the planting hole. The purpose of this step is to prevent an interface between the amended soil and the existing site soil that limits water movement in either direction, due to significant differences in soil properties (Hammerschlag and Sherald, 1985).

Figure 27. Amending soil at a planting hole with compost decreases bulk density, improves water- and nutrient-holding capacity, and increases nutrient levels.

After incorporating soil amendments, each planting hole should be marked with flagging so it can be easily found at planting time. Trees should be planted as soon as possible after amending the soil in order to prevent erosion, so a temporary cover crop such as clover may be necessary to stabilize the soil until the planting project is completed.

The planting plan for the reforestation project should include a site sketch indicating the boundaries of the areas to be amended or the location of planting holes, an equipment list, and an implementation schedule for soil amendments. Existing vegetation such as turf or weeds may need to be removed from the site before implementation. A sod cutter, brush mower, or ripper may be used to remove turf, weeds, shrubs, or other vegetation. An alternative is to incorporate the vegetation into the existing soil during subsoiling or tilling, provided the plants are nonwoody and noninvasive. Incorporating the vegetation into the soil will require approximately 8 weeks before replanting the site because of the time required for the incorporated material to decompose (Chollak and Rosenfeld, 1998). Equipment needed for soil amendments is listed in Table 15.

Table 15. Equipment for Urban Soil Amendment Projects

Equipment	Use
Sod cutter or Bush Hog	Removing vegetation
Various soil amendments	Improving soil quality
Measuring tape	Measuring planting area, quantifying amendment application rates
Wheelbarrow	Removing rocks, rubble, vegetation, excess soil
Gloves	Handling soil amendments
Pickup truck	Disposing of trash, vegetation, and excess soil from the site, and delivering amendments
Tarp	Storing soil from planting hole
Large bucket	Mixing soil amendments
Shovel, spade, or auger	Digging planting holes

Costs of Soil Amendments

The cost of soil amendments will vary depending on the methods used, the type of labor, and the source of compost. If free compost is available through public works or other local department, project costs will be greatly reduced. For example, estimated costs of delivered compost per cubic yard range from $11 to $20 (Chollak and Rosenfeld, 1998). Based on these estimates, the cost of compost amendments per planting hole would range from $0.66 to $1.20 per tree, for a tree with a 6-inch diameter root ball, assuming soils are amended to a depth of 2½ feet.

Chapter 6. Planting, Inspection, and Maintenance Techniques

Key elements of tree planting include obtaining and storing plant materials, planting the trees, post-planting tree protection, and maintenance and inspection of newly planted trees. This chapter describes each of the planting and maintenance elements essential to ensure a healthy future for new trees and shrubs.

Obtaining and Storing Plant Materials

This section describes methods for obtaining and storing plant materials before the planting day.

Obtaining Plant Materials

One potentially frustrating aspect of tree planting is spending a lot of time evaluating the site and selecting just the right tree species, only to find that some of the species are not available for purchase. Designers should devote some effort to researching and determining the best places to purchase their plant materials and planning ahead for ordering and purchase. Availability is usually related to the type of plant material and the species.

In general, there are three types of sources for obtaining plant materials: private nurseries, government nurseries, and nonprofit organizations. Table 16 provides a description of each source. Web resources for obtaining plant materials are provided below:

- American Forests Historic Tree Nursery Store
  www.historictrees.org/store.htm

- National Arbor Day Foundation Tree Store
  www.arborday.org/shopping/trees/trees.cfm

- Natural Resources Conservation Service Plant Materials Program Sources of Seed and Plants
  http://plant-materials.nrcs.usda.gov/technical/biorip/sources.html

- North American Native Plant Society Plant Sources
  www.nanps.org/sources/frame.shtml

- Plant Native's Native Plant Nursery Directory
  www.plantnative.org

- Reforestation, Nurseries, and Genetics Resources Plant Materials Directory
  www.rngr.net/Applications/directory

Table 16. Sources of Plant Materials	
Plant Material Source	**Description**
Private nurseries	Wide range of local private nurseries, some sell wholesale, and some specialize in natives. Typically have the widest selection of species and stock. Some may not have a wide selection of natives.
Government nurseries	Includes state nurseries and other government nurseries, such as Natural Resources Conservation Service Plant Materials Centers. Typically have native tree seedlings available for purchase in large quantities for community reforestation projects. May be limited to seedlings or small stock.
Nonprofit organizations	Wide range of local nonprofit organizations or national nonprofits, such as American Forests and National Arbor Day Foundation. Typically have native tree seedlings available for purchase at low cost for reforestation projects.

In general, it is best to order from a nursery that grows their plants locally, since the trees will already be adapted to the local climate. It is also good to check with references who have used the nursery before. Place orders early (e.g., before early spring) to ensure the best selection, and consider ordering 10 to 15 percent more trees than are actually needed for replacements. In most cases, plants should not be paid for until delivery so the plants can be inspected to ensure they are in good condition. Quality of nursery stock is very important; for example, a healthy rootball is critical to a tree's ultimate survival. When inspecting nursery stock, look for the following indicators of potential defects in the root ball (Polomski and Shaughnessy, 1999):

- Trunk moves or appears to be loose in the root ball when pushed (tree may not be stable)
- Top layer of roots are more than 1-2 inches below the surface of the soil (tree planted too deeply)
- Large roots escaping from bottom of container (when pruned, may cause tree decline)
- Container does not slide easily off root ball (tree may be pot-bound)
- Many circling roots on outside of root ball (tree may be pot-bound)
- Black roots on surface of root ball (indicates damage from extreme temperatures or overwatering)

Polomski and Shaughnessy (1999) provide additional guidance on inspecting nursery-grown trees for problems in the root ball, branches, and overall health, while ISA (2005) provides additional guidance on determining if nursery stock has been planted too deeply. If trees are being picked up from the nursery rather than delivered, protect them with a cover during transportation, to avoid overheating and desiccation and damage to leaves if leafed out. If trees will not be planted immediately, a temporary storage location must be identified.

Storing Plant Materials

Proper storage and preparation of plant materials *before* planting is essential to ensure that new trees and shrubs will establish and thrive. After receiving plant material, it should be kept covered, shaded, and moist or watered until placed in the ground. The root balls of balled and burlapped stock and the packing of bare root stock should be thoroughly watered and kept moist with a covering of peat moss, straw or saw dust until planted (Palone and Todd, 1998). Container material is least susceptible to moisture stress and will store well if properly watered. Bare root trees are the most susceptible to desiccation and should be stored in a cool place until planting. If possible, bare roots should be dipped in hydrogel or muddy water, then stored immediately in large plastic bags until planting. Hydrogel is a synthetic water-absorbing polymer available in many brands. A sample method for dipping trees in hydrogel can be found in Buckstrup and Bassuk (2000). If hydrogel is not used, the tree roots should be soaked in water for 12-24 hours before planting (Buckstrup and Bassuk, 2003).

Planting Techniques

This section describes planting techniques for various plant materials, planting on steep slopes, and methods to encourage natural regeneration.

Planting Techniques for Various Plant Materials

Planting techniques and optimal planting seasons vary for different plant materials, and are presented in Table 17. General planting guidance that is appropriate for all plant materials includes digging a hole that is no deeper than the root ball or mass but two to three times wider than the spread of the root ball or mass because the majority of the roots on a newly planted tree will develop in the top 12 inches of soil and spread out laterally. Thus, the wider the area of soil that is prepared (amended or broken up) before planting, the more successful the planting (Trowbridge and Bassuk, 2004). Make sure the bottom of the hole is undisturbed or compacted and level to prevent sinking and shifting of the tree after planting.

Table 17. Tree Planting Techniques

Plant Material	Planting Technique	Planting Season
Bare root	Hand plant with shovel, dibble bars, or mattocks (Can be machine planted at large sites with compatible soils if cost-efficient)	Fall,* early spring
Container grown	Hand plant or use mechanical planting tools (e.g., auger)	Spring or fall, summer if irrigated
Balled and burlapped	Use backhoe (or other specialized equipment) or hand plant.	Spring or fall

Source: Palone and Todd (1998), WSAHGP (2002), NJDEP (2004)

*One Cornell University study showed that bare-root trees planted in fall grow better during the first growing season than those planted in spring (Trowbridge and Bassuk, 2004).

One of the most important planting guidelines is too make sure the tree is not planted too deeply. The root collar, the lowest few inches of trunk just above its junction with the roots (often indicated by a flare), should be exposed (Flott, 2004). Trees planted too deeply have buried root collars, and are weakened, stressed, and predisposed to pests and disease (Flott, 2004). Trees planted too deeply can also form adventitious roots near the soil surface in an attempt to compensate for the lack of oxygen available to buried roots. Adventitious roots are not usually large enough to provide support for a large tree and may eventually lead to collapse (Flott, 2004). ISA (2005) provides additional guidance on how to avoid planting too deeply. It is generally better to plant the tree a little high, that is, with the base of the trunk flare 2 to 3 inches above the soil, rather than at or below the original growing level (ISA, 2003b).

Proper handling during planting is essential to avoid prolonged transplant shock and ensure a healthy future for new trees and shrubs. Trees should always be handled by the root ball or container, never by the trunk. Specific instructions for planting a tree are presented in Box 5, including variations for specific plant materials. Specifications for planting a tree are illustrated in Figure 28.

BOX 5. INSTRUCTIONS FOR PLANTING A TREE

1. Dig a hole that is two to three times as wide as the root spread, container diameter, or balled and burlapped root ball. The hole should be no deeper than the root ball height or depth of soil in the container. The hole should be shallow enough that the root collar of the tree will be exposed when planted.

2. Break up any compacted soil on the sides of the planting space and make sure the bottom of the hole is firm to prevent settling.

3. Remove all string or wiring from bare root and container grown trees. Remove the container from container grown trees and shake off any excess soil.

4. Prune any dead, diseased, broken, or circled roots on bare root or container grown trees.

5. Place the tree upright in the hole (mechanical equipment may be needed for large trees). Make sure roots of bare root trees are relatively straight and spread out. Straighten the tree in the hole and check that the root collar is visible at soil level.

6. Cut burlap, rope, and wire basket away from root ball on balled and burlapped trees. Remove entirely if possible.

7. Gently pack backfill soil around base of root ball. Allow rest of backfill to settle naturally, use water to settle, or tamp lightly. Continue to fill the planting hole with soil up to the tree base.

8. Install tree shelters or stakes if needed. If staking is necessary, use one or two stakes with separate flexible ties and remove after 1 year. Stakes should be extended into undisturbed soil.

9. Apply a 2- to 4-inch layer of mulch over the entire rooting area, leaving a 3-inch circle of bare soil around the trunk.

10. Water the tree thoroughly.

Sources: Buckstrup and Bassuk (2003), DOD (1996), Flott (2004), Greenfeld and others (1991), Haefner and others (2002), NVRC (1997), Palone and Todd (1998), Trowbridge and Bassuk (2004), WSAHGP (2002)

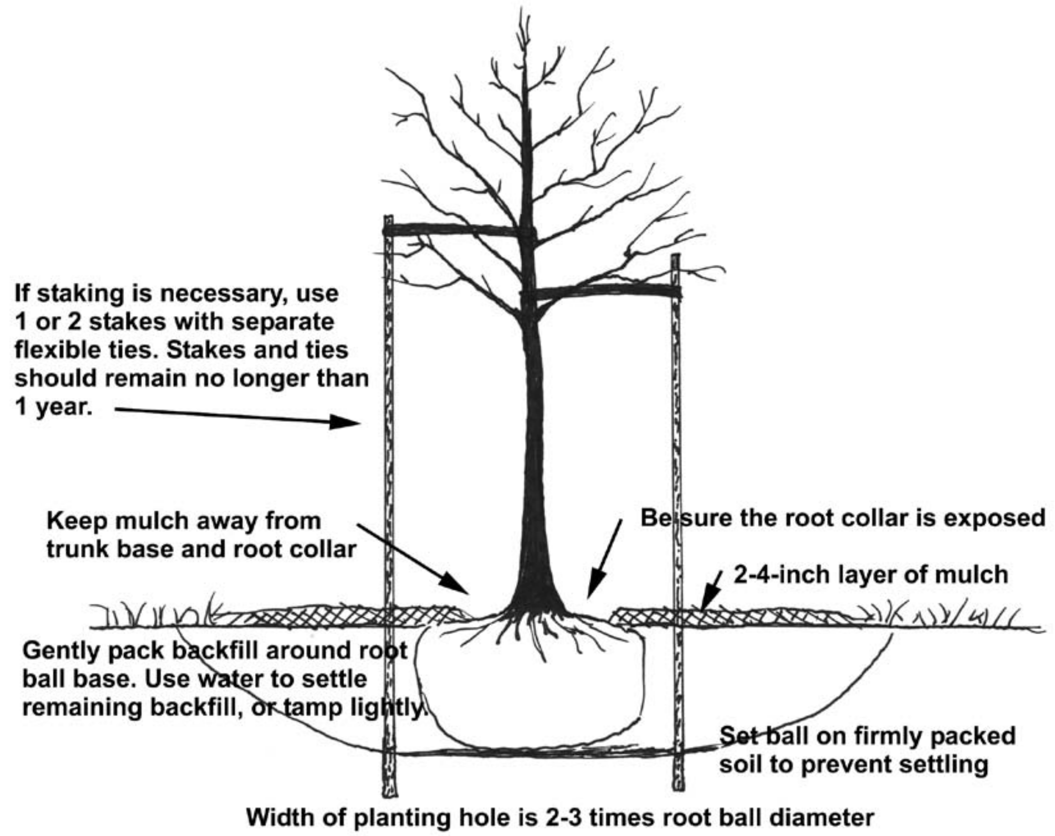

Figure 28. Following approved tree planting specifications improves chances of tree survival. (Adapted from Flott, 2004 and ISA, 2003b)

Planting on Steep Slopes

Steep slopes will require additional measures to ensure planting success and reduce erosion, especially if the slope receives storm water runoff from upland land uses. Depending on the steepness of the slope and the runoff volume, rill or gully erosion may occur on these slopes, requiring a twofold approach: controlling the storm water and stabilizing the slope. Chapter 4 provides some guidance on controlling storm water runoff at a planting site.

Erosion control blankets are recommended to temporarily stabilize soil on slopes until vegetation is established (Caraco, 2000; Morrow and others, 2002). Erosion control fabrics come in a variety of weights and types, and should be combined with vegetation establishment such as seeding. Other options for stabilizing slopes include applying compost or bark mulch, plastic sheeting, or sodding (Caraco, 2000). For more information on erosion control blankets, see Schueler and Brown (2004).

Trees will add stability to slopes because of their deep roots, provided they are not planted by digging rows of pits across a slope (Morrow and others, 2002). Trees and shrubs should be phased in gradually after grass is established or planted simultaneously provided low, slow-growing grasses are used to avoid competition (Morrow, and others, 2002). Required maintenance will include mowing (if slopes are not too steep), and repairing bare or eroded areas.

Planting methods for slopes steeper than 3:1 (1 foot vertical change for every 3 horizontal feet) involve creating a level planting space on the slope (see Figure 29). A terrace can be dug into the slope in the shape of a step. The existing slope can be cut and the excavated soil can be used as fill. A low soil berm (or rock berm) can be formed at the front edge of each step or terrace to slow the flow of water. Trees can also be planted in clusters on slopes (using the above method) to limit potential for desiccation. Staggering tree placement and mulching will prevent water from running straight downhill. Figure 30 illustrates a tree cluster, which uses trees to treat storm water runoff.

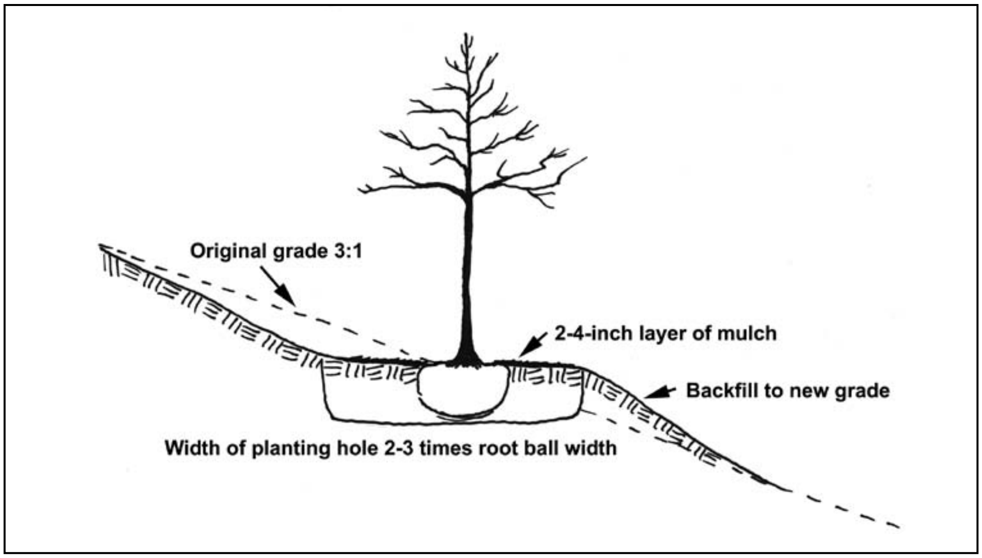

Figure 29. The specifications for planting on a steep slope create a level planting space.

Figure 30. A tree cluster planted on the side slope of a storm water pond helps to treat storm water runoff.

Encouraging Natural Regeneration

Natural regeneration is the process by which trees and forests establish from seeds produced and germinated on site. Most of the eastern United States gets enough rain that trees will eventually regenerate in sites where they are not kept out by mowing, cultivation, browsing, chemicals, or land development. Natural regeneration is the least expensive option for establishing forest cover on a site, and should be considered as an option when evaluating planting sites. One major disadvantage of this technique in urban areas is the high potential for regeneration of invasive or nonnative species with cessation of mowing. Table 18 summarizes the advantages and disadvantages of natural regeneration.

Table 18. Advantages and Disadvantages of Natural Regeneration

Advantages	Disadvantages
• Lower establishment costs • Less labor and equipment required • New seedlings have good early root development • Less soil disturbance and soil erosion • Trees are adapted to the area • Creates diverse stands of varying ages • Enhances native wildlife • Avoids transplant shock • Excess seedlings from dense stands can readily be transplanted to new areas	• Regeneration of canopy may take longer • Less control over species, spacing, and density • Trees may not grow where most advantageous for multiple uses or maintenance • Requires viable seed bank • Delays in regeneration can occur due to environmental conditions or inadequate seed fall • Selective regeneration of particular species may occur due to deer, lack of seed dispersal, or lack of regeneration trigger (such as fire)

Source: Featherstone (2000), Willistin and others (1998)

Natural regeneration in urban areas may be limited due to loss of seed bank, poor seedbed conditions, high pedestrian traffic, soil compaction, and competition from invasive species. A thorough assessment of the site (see Chapter 2) will help determine if regeneration is a feasible method of restoration and identify ways to encourage regeneration. In general, sites that are good candidates for natural regeneration have these characteristics (Hairston-Strang, 2005):

- Desirable tree seed sources nearby (Figure 31)
- Adequate seed dispersal methods,
- Bare mineral soils with good seed-to-soil contact,
- Low compaction,
- Controlled deer population,
- Limited invasive species, and
- Current vegetative cover that does not consist of thick sod-forming grass, such as fescue.

Adequate seed sources include light-seed species (e.g., maple, sycamore, ash, pine, yellow poplar) located upwind of the site (can be fairly far away), heavy-seeded species (e.g., oaks, hickories) within 300 feet upslope, or existing tree species on the site that produce root sprouts (e.g., aspen, black locust, persimmon) (Hairston-Strang, 2005). If perches for birds are present, the potential for seed dispersal is greater due to droppings.

Figure 31. This natural regeneration site has some existing trees that provide a seed source.

Sites that are probably not good candidates for natural regeneration include those with severe soil problems (e.g., very compacted or shallow soils), high density of invasive species, uncontrolled deer populations, existing vegetation in poor condition, or high pollution input (Sheahan, 1998; Hairston-Strang, 2005). Sites that are not ideal candidates can be helped along using several techniques, including these: improving soil conditions; controlling invasive plants; installing fencing or other methods to control deer; discing (mixing) or herbicide application, or both, to release the seed bank and allow trees to seed in sod-forming grasses; and installing perches to encourage seed spread by birds. To encourage natural regeneration as a way to fill in gaps in canopy of urban forest remnants, forest litter should be left on the ground. This encourages natural regeneration by providing biomass material for regrowth and habitat for insects and animals (Willistin and others, 1998).

Maintenance for natural regeneration sites is similar to that for reforestation sites: watering, weeding, and mulching. Signage should be installed to restrict mowing and inform the public of the purpose of the project. Monitoring should be performed regularly to assess plant growth and survival as well as species composition. Supplemental plantings may be necessary if invasive species are dominant or for species that have difficulty regenerating to provide diversity on the site.

Post-Planting Tree Protection

Mulch, stakes, tree shelters, and signage are commonly used to protect newly planted trees from damage by wind, pedestrian traffic, deer, vandalism, and other potential impacts. Each is described below.

Mulch

Once the tree has been properly planted, 2 to 4 inches of organic mulch should be spread over the soil surface out to the drip line of the tree (other weed control options, such as weed mats, are discussed in the following section). If planting a cluster of trees, mulch the entire planting area. Slow-decomposing organic mulches, such as shredded bark, compost, leaf mulch, or wood chips provide many added benefits for trees. Mulch that contains a combination of chips, leaves, bark, and twigs is ideal for reforestation sites. (ACB, 2000; ISA, 2003a). Grass clippings and sawdust are not recommended as mulches because they decompose rapidly and require frequent application, resulting in reduced benefits. Mulch has many benefits, including these (CBF, 2001; ISA, 2003a):

- Retains soil moisture by preventing evaporation and promoting infiltration
- Moderates soil temperature extremes

- Reduces competition from grass and weeds
- Prevents erosion
- Prevents damage to the trunks of trees by lawn equipment
- Enriches the soil by adding organic matter and nutrients as it decomposes
- Prevents soil compaction

For well-drained sites up to 4 inches of mulch may be applied, and for poorly drained sites a thinner layer of mulch should be applied. Mulch should never be more than 4 inches deep or applied right next to the tree trunk; however, a common sight in many landscaped areas is the "mulch volcano" (Figure 32). This over-mulching technique can cause oxygen and moisture-level problems, and decay of the living bark at the base of the tree. A mulch-free area, 2- to 3-inches wide at the base of the tree, is sufficient to avoid moist bark conditions and prevent decay (ISA, 2003a).

Figure 32. A mulch volcano (left) can cause the trunk to rot; a properly mulched tree (right) has space around the trunk.

Stakes

Studies have shown that trees will establish more quickly and develop stronger trunk and root systems if they are **not** staked at the time of planting (ISA, 2003b). Staking for support may be necessary only for top-heavy trees or at sites where vandalism or windy exposure are a concern (Buckstrup and Bassuk, 2003; Doherty and others, 2003; ISA, 2003b).

If staking is necessary for support, two stakes used in conjunction with a wide flexible tie material will hold the tree upright, provide flexibility, and minimize injury to the trunk. Figure 28 on page 63 provides a schematic for staking a tree. To prevent damage to the root ball, stakes should be placed in undisturbed soil beyond the outer edges of the root ball. Perhaps the most important part of staking is its removal. Over time, guy wires (or other tie material) can cut into the growing trunk bark and interfere with the movement of water and nutrients within the tree. Staking material should be removed within 1 year of planting (Doherty and others, 2003).

Tree Shelters

Tree shelters are 2- to 5-foot tall plastic tubes that enclose seedlings to protect them from lawnmowers, weeds, wind, animals, drought, and trampling (Figure 20 on page 43). Tree shelters also create a greenhouse effect around seedlings that significantly improve growth rates and establishment success for many species (Sweeney, 1993). This can be especially crucial for tree survival on difficult or dry upland sites (Meyer, 1993; Palone and Todd, 1998; Sweeney, 1993). Tree shelters do not work as well in shaded conditions and are recommended for deciduous trees only (Sweeney, 1993).

Tree shelters should be removed 2 to 3 years after installation (Sweeney, 1993; Palone and Todd, 1998). They must be maintained to ensure that they are stable, and kept free of shading weeds in summer and dead grasses in winter (Sweeney, 1993). Tree shelters also require wooden stakes for support, and a plastic mesh cap to keep birds and wasps from nesting in them (Meyer, 1993; Palone and Todd, 1998; Sweeney, 1993). See Palone and Todd (1998) for sources of tree shelters and Hairston-Strang (2005) for installation instructions.

Signage

In most urban areas, the best protection for any reforestation project is installing signs to increase its visibility. Signage can help prevent un-intentional trampling or mowing, and educates the public about the purpose of the project (Figure 33).

Figure 33. Signage is used to prevent mowing and to inform the public of a reforestation project.

Tree Inspection and Maintenance

Every urban tree planting site requires regular inspection and maintenance such as watering, weed control, pruning, and pest management. Fertilization is usually not needed for newly planted trees, but may be beneficial later, depending on soil and growing conditions. The Tree Care Industry Association (2004) provides guidance on tree fertilization. Inspection, replacement, and removal of tree shelters and stakes should also be part of a maintenance plan. Planting sites should be regularly inspected to assess plant growth, survival, and species composition. Based on inspection results, supplemental plantings may be needed to replace trees that did not survive.

An inspection and maintenance schedule should be created for each reforestation site, should include immediate post-planting inspection and maintenance, and should extend at least 3 to 5 years from initial planting. Most inspection and maintenance tasks will take place during the growing season; however, it may be necessary to conduct certain tasks during the dormant season (e.g., removal of certain invasive species). Trained volunteers (e.g., homeowners' association, local civic group) or public works staff typically will be responsible for tree maintenance, while tree inspectors are usually trained foresters, arborists, or other professionals who can diagnose tree health. A sample inspection schedule is provided in Table19, and each activity is explained in further detail in the next section.

Table19. Example Inspection and Maintenance Schedule*					
Inspection and Maintenance Activity	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Regularly inspect tree health and survival	X	X	X	X	X
Water trees	X	X	X		
Remove tree shelters			X	X	X
Remove stakes and wires		X			
Implement invasive species and noxious weed control methods as needed	X	X	X	X	X
Prune damaged, dead, or diseased branches		X	X	X	X
Implement Integrated Pest Management methods as needed	X	X	X	X	X
Install supplemental plantings if desired		X	X	X	X

*Adapted from Hairston-Strang (2005) and Palone and Todd (1998)

Inspection

Initial planting inspection

Each tree should be inspected for proper planting and post-planting protection immediately after initial planting. Any problems should be corrected immediately. A specific checklist for initial planting inspection may include the questions in Box 6.

BOX 6. SAMPLE CHECKLIST FOR INITIAL INSPECTION OF A PLANTING SITE

- ☐ Is the tree planted at the correct height?
- ☐ Has a tree shelter been installed properly?
- ☐ Are stakes installed properly (if needed)?
- ☐ Has mulch been properly applied around trees?
- ☐ Has the tree been well watered?
- ☐ Has flagging been installed to help locate the tree?

Long-term inspection

For newly planted trees, transplant shock is common and causes a great deal of stress on a new tree. For this reason, newly planted trees must be inspected more frequently than established trees. The time it takes for a tree to become established varies with the size at planting, species, stock, and site conditions, but generally, trees should be inspected every few months during the first 3 years after planting, to identify problems and implement repairs or modify maintenance strategies (WSAHGP, 2002).

After the first 3 years, annual inspections should be sufficient to check for problems. Trees may also be inspected after major storm events for any damage that may have occurred. The inspection should take only a few minutes per tree, but prompt action on any problems encountered results in healthier, stronger trees. Aside from correcting problems and ensuring survival, inspection data can help to refine and improve the success of future plantings.

A checklist for long-term inspection of urban tree planting sites is given in Box 7.

BOX 7. CHECKLIST FOR LONG-TERM INSPECTION OF A PLANTING SITE

- ☐ Assess tree vigor and overall health (see Greenfield and others, 1991 for guidance).
- ☐ Count the number of living trees and record species to determine survival rates.
- ☐ Evaluate cause of mortality for dead trees and recommend supplemental plantings if deemed appropriate.
- ☐ Determine if pruning is need for damaged, dead, or diseased branches.
- ☐ Inspect trees for signs of insect damage and disease.
- ☐ Determine if stakes need to be adjusted or removed.
- ☐ Determine if tree shelters need to be adjusted, replaced, or cleared of wasps.
- ☐ Evaluate if additional weed control is needed.
- ☐ Determine if natural regeneration is occurring and record species.

Repairs should be completed as soon as possible. If a significant number of trees are dead or damaged, supplemental plantings may be done after evaluating and addressing the cause of mortality or damage. It may not be economically desirable to replace trees if the cause of damage is unknown or is uncontrollable. Hairston-Strang (2005) provides guidance on determining the cause of tree mortality.

Watering

Proper water management is perhaps the most crucial maintenance activity to ensure survival of newly planted trees. If plans are not made to water new trees, they may die during periods of drought. Over watering can also be fatal to young trees and will cause leaves to turn yellow or fall off in older trees. Although watering can be costly and time-consuming, it is well worth the effort. Watering options include regular or soaker hoses, sprinklers, buckets, drip irrigation, or installation of larger capacity watering tanks or irrigation systems. Buckets or jugs with very small holes can be used to create a crude drip system (Sedbrook, 2005). The local fire department or public works can also provide help in watering. Techniques that may help increase plant survival when it is too costly to irrigate include these (Palone and Todd, 1998):

- Monitor the rainfall and groundwater at the site during the site assessment to evaluate whether it is suitable for planting with no supplemental irrigation.
- Plant during the rainy season.
- Choose species that are tolerant of both dry and wet conditions.
- Mulch regularly.
- Dip plant roots in water before planting.
- Use storm water runoff at the site as a source of irrigation water where feasible (see Chapter 4 for information on evaluating storm water runoff).

Some rules of thumb for watering include these:

Figure 34. A soaker hose is an efficient way to water newly planted trees.

- Water newly planted trees regularly (at least once a week) during the first growing season. Water less frequently (about once a month) for the next two growing seasons. After three growing seasons, water only during drought. The exact watering frequency will vary for each tree and site.
- A general horticultural rule of thumb is that trees need 1 inch of rainfall per week during the growing season (Petit and others, 1995). Monitoring soil moisture, using watering systems with timers and shutoff valves, and monitoring rainfall at the site are all helpful in ensuring the tree gets the right amount of water.
- Water trees deeply and slowly near the roots. Light, frequent watering of the entire plant can actually encourage roots to grow at the surface. Soaker hoses (Figure 34) and drip irrigation work best for deep watering of trees and shrubs.
- Continue watering until mid-fall, tapering off during lower temperatures. Watering can continue one to two times per month through the winter, but only when the ground is not frozen.

Pruning

Pruning is usually not needed for newly planted trees but may be beneficial for tree structure. If necessary, prune only dead, diseased, broken or crossing branches at planting (Doherty and others, 2003; Trowbridge and Bassuk, 2004). As the tree grows, lower branches may be pruned to provide clearance above the ground, or to remove dead or damaged limbs that sprout from the trunk. Refer to ANSI A300 Standards (Part 1 Pruning) for Tree Care Operations for pruning guidance for mature trees or make sure that a certified arborist does the pruning (TCIA, 2004).

Weed Control

Controlling weeds is a cost-effective method to accelerate the growth of tree seedlings. For trees larger than seedlings, only a few years of weed control may be needed, as trees will soon be tall enough to compete with the herbaceous layer. Mowing and mulching are two common methods of weed control. Additional control methods are discussed in Chapter 5.

Mowing is an option for weed control where sufficient space exists between plantings for mower access. Drawbacks of mowing are that it can inhibit natural regeneration between plantings, and mulch or tree shelters are necessary to protect tree trunks from mower strikes (Palone and Todd, 1998). If mowing is used, mow twice a year during the first three growing seasons to a height of 6 inches, but do not let weeds get higher than 12-14 inches before mowing (ACB, 2000; WSAHGP, 2002). Mowing immediately around newly planted trees is not recommended as this may actually increase nutrient uptake in the herbaceous layer, and retard seedling growth (Palone and Todd, 1998).

For mulched areas, weeding should be a regular part of the maintenance schedule. Mulch twice a year—in late spring and during leaf fall. A well-aged hardwood mulch has good moisture retention and weed control benefits. Check the depth of mulch regularly to maintain a 2- to 4-inch depth. Do not add mulch if there is a sufficient layer in place. Rake the old mulch to break up any matted layers and to refresh the appearance. If mulch is piled against the stems or tree trunks, pull it back several inches so that the base of the trunk and the root crown are exposed (ISA, 2003a).

Mulch or any other weed control method will never guarantee complete eradication of weeds at a site. Most likely, a combination of several methods will be necessary, and some form of weed control will be necessary over the long term. Several products that are frequently used in combination with mulch include weed mats, landscape fabric, and shredded newspaper; all are effective in reducing weed rooting within organic mulch beds.

Integrated Pest Management

No one method of controlling pests is ideal; rather, a combination of biological, physical, chemical, and cultural methods should be used. This approach is often referred to as Integrated Pest Management (IPM), and entails taking a comprehensive look at the available methods, considering their effect on the surrounding environment, and addressing both initial removal and long-term control. IPM typically includes biological control methods, where beneficial insects are used to control populations of insect pests. Pesticides and herbicides are used only as a last resort, and the least toxic alternative is preferred. For more information on Integrated Pest Management, refer to the University of Maryland Department of Entomology Web site: www.mdipm.umd.edu/.

Appendix A. Field Sheet for the Urban Reforestation Site Assessment (URSA)

Instructions for completing this URSA field sheet are in Chapter 2.

1. General Site Information

Location:

Property owner:

Current land use:

2. Climate

USDA plant hardiness zone:

Sunlight exposure:

- ☐ Full sun (6 hours or more of direct sun per day)
- ☐ Part sun or filtered light (< 6 hours per day)
- ☐ Shade (< 3 hours of direct sun per day)

Microclimate features (check if present):

- ☐ High wind exposure
- ☐ Re-reflected heat load
- ☐ Other:

3. Topography

Steep slopes

Are any slopes > 15% present in the proposed planting area? Y/N

If Yes, estimate slope:

Low-lying areas

Are any low-lying areas present in the proposed planting area? Y/N

Notes:

4. Vegetation

Regional forest association (or dominant species from reference site):

Current vegetative cover (check all that apply and note percent of planting area):

- ☐ Mowed turf: _____%
- ☐ Other herbaceous: _____%
- ☐ None: _____%
- ☐ Trees or shrubs: _____%

Note species to be preserved:

Are invasive plants or noxious weeds present? Y/N

If Yes, note species and percent coverage at site.

Adjacent vegetative cover:

Is forest present? Y/N

If Yes, note dominant species:

Are invasive plants or noxious weeds present? Y/N

If Yes, note species and percent coverage at site.

5. Soils

Texture:

- ☐ Clay
- ☐ Loam
- ☐ Sand

Drainage:

- ☐ Poor (< 1" per hour)
- ☐ Moderate (1" - 6" per hour)
- ☐ Excessive (> 6" per hour)

Compaction:

- ☐ None
- ☐ Moderate
- ☐ Severe

pH:

- ☐ Acid (5.0 – 6.8)
- ☐ Neutral (6.8 – 7.2)
- ☐ Alkaline (7.2 – 8.0)

Other soil features (check if present and describe:

- ☐ Active or severe soil erosion
- ☐ Potential soil contamination
- ☐ Debris and rubble in soil
- ☐ Recent construction or other soil disturbance
- ☐ Other:

Soil Chemistry (Optional)

List results of soil tests if applicable (e.g., levels of phosphorus, salt, or organic matter in the soil).
Describe any visual indicators of soil quality.

6. Hydrology

Site hydrology:

- ☐ Upland
- ☐ Riparian

Note: For riparian planting sites where planting is proposed on both stream banks, fill out this section for each bank separately

Stormwater runoff to planting site (check all that apply):

- ☐ Bypasses site in pipe
- ☐ Upslope drainage area outfalls to site
  Note diameter of pipe outfall: ______
- ☐ Open channel directs flow across or around the site
- ☐ Shallow concentrated flow (e.g., evidence includes rills, gullies, sediment deposits)
- ☐ Sheetflow
- ☐ Unknown

Contributing flow length:

Slope: ______%
Length: _______ft
Dominant cover type:

- ☐ Impervious
- ☐ Pervious

Floodplain connection (riparian areas only):

Are levees present? Y/N
Bank height: _____ft
Depth to water table (optional): _____ft

Stream order: _______

Contributing Flow Length Sketch:

7. Potential Planting Conflicts

Space limitations (check if present, and note height of overhead wires, signs and lighting):

- ☐ Overhead wires: _____ft
- ☐ Pavement
- ☐ Structures
- ☐ Signs: _____ft
- ☐ Lighting: _____ft
- ☐ Underground utilities
  Note type:
- ☐ Other:

Other limiting factors (check if present and describe below):

- ☐ Trash dumping/debris
  Note type of trash, volume (estimated pickup truck loads), and source if known:
- ☐ Deer, beaver or other animal impacts
- ☐ Mowing conflict (e.g., site is mowed regularly)
- ☐ Wetland present
- ☐ Insect infestation or disease
- ☐ Heavy pedestrian traffic
- ☐ Other:

Notes:

Local Ordinance Setbacks

Check local ordinances or utility requirements and note any required setbacks from these features.

8. Planting and Maintenance Logistics

Site access (check if present):

- ☐ Delivery access for planting materials
- ☐ Temporary storage areas for soils, mulch, etc.
- ☐ Heavy equipment access
- ☐ Volunteer parking
- ☐ Nearby facilities for volunteers

Party responsible for maintenance (if known):

Water source (check all that apply):

- ☐ Rainfall only
- ☐ Storm water runoff
- ☐ Hose hook-up nearby
  Note distance from hook-up to planting area (ft):
- ☐ Irrigation system in place
- ☐ Overbank flow from river or stream
- ☐ Fire hydrant nearby
- ☐ Other:

9. Site Sketch

Sketch the site below and include the following features at a minimum:

- ☐ Property boundary, landmark features (e.g., roads, streams) and adjacent land use/cover
- ☐ Boundary and approximate dimensions of proposed planting area
- ☐ Variations in sun exposure, microclimate, and topography within planting area
- ☐ Current vegetative cover, location of trees to be preserved, and invasive species
- ☐ Location and results of soil samples (if variable)
- ☐ Flow paths to planting area and contributing flow length
- ☐ Above or below ground space limitations (e.g., utilities, structures)
- ☐ Other limiting factors (e.g., trash dumping, pedestrian paths)
- ☐ Water source and access points
- ☐ Scale and north arrow

Appendix B. Urban Tree Selection Guide

Once planting sites have been selected and the Urban Reforestation Site Assessment has been conducted, the tree selection guide in this appendix can be used to narrow the field of possible choices for planting in the urban environment. Tree species can be selected based either on their tolerance to environmental conditions at the site (Chart 1) or on desired tree characteristics, such as small size for use near overhead wires (Chart 2).

When using the charts in this appendix, keep in mind that a given tolerance for one variable may be influenced by another variable. For example, sun exposure may influence a species' ability to manage a prolonged drought, or a species which grows to its fullest in sandy textured, well-drained soils may not persevere when planted in a windy (thus drying) setting. With this in mind, these charts should be used as a "first-cut" guide to tree selection for a given set of circumstances. To refine the species selection and to ensure success of the planting, consult local horticulturists, arborists, landscape architects, or other natural resource professionals who are familiar with the geography and site specifics of the planting area.

Tree species in this appendix were selected on the basis of two characteristics: the overlap of their hardiness capability with the climate of the Mid-Atlantic and Northeast, and Midwest U.S. regions; and their ability to tolerate one or more variables typically associated with urban environments (e.g., salt tolerance, compaction). The information about each species was derived from a variety of primary sources, which are listed below. When data elements were not fully available from these sources or elements were in conflict, the other resources, also listed below, were used to validate information.

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Definitions Used in Chart 1

Hardiness Zone – This is the acceptable Hardiness Zone that the tree is capable of growing in. Hardiness Zones are determined by the average minimum temperature of a given location. A higher Hardiness Zone means a warmer climate is needed to sustain a healthy specimen. Data are based on the USDA Plant Hardiness Zone Map.

Soil Moisture – Four subheadings indicate the amount of moisture that is required for a plant to survive. Many plants have the ability to survive in many different levels of soil moisture. Note that it is critical to give newly transplanted trees several years of supplemental watering to hasten their establishment before expecting them to possess wider soil moisture level tolerance.

Sun Exposure – **Full sun** plants require more than 6 hours of direct sunlight a day, **partial shad**e plants tolerate direct sun for less than 6 hours a day or filtered light for most of the day, and **full shade** plants tolerate little or no direct sunlight or less than 6 hours of filtered sunlight a day.

Soil Components – Each soil type has a certain proportion of sand, loam, and clay. Soils with a high proportion of sand generally hold little water due to sand's large particle size around which water passes. Soils with a high proportion of clay are relatively impermeable. The tolerance ratings in this section provide general characteristics of the soil needed by a particular tree species.

Drought Tolerance – This is the plant's ability to survive a single period of very little rainfall. Some plants are able to do this despite having unusually moist soil requirements.

Flood Tolerance – Tolerant trees can survive when flooded for 30 to 40 percent of the growing season, medium trees can survive when flooded for 10 to 30 percent of the growing season, and intolerant trees will not survive if flooded for more than 10 percent of the growing season.

Pest/Disease Tolerance – This field notes the relative susceptibility of tree species to pest/disease problems.

Soil Compaction – Compacted soil inhibits root growth. Some trees are able to grow in compacted soils, nonetheless, which would prove beneficial when planting trees on degraded sites.

Salt Tolerance – This refers to soil salinity, not aerosol salt. Soil tolerance is a consideration in those areas where road salt is used to de-ice the roads during the winter months.

pH level – Trees that require acid soil are listed as 5.0 – 6.8. Trees that require neutral soil are listed as 6.8 – 7.2. Trees that require alkaline soil are listed as 7.2 – 8.0.

Parts of Chart 1 are marked with shaded boxes according to the following legend:

T	= tolerant
M	= moderately tolerant
I	= intolerant
	= unknown

Chart 1. Tree Tolerance to Environmental Conditions

Common Name	Scientific Name	Hardiness Zone	Soil Moisture			
			Saturated or wet	Moist, well drained	Periods of dry	Prolonged drought
American basswood	*Tilia americana*	3 to 8	M	T	T	I
American beech	*Fagus grandifolia*	3 to 8	I	T	T	M
American elder	*Sambucus canadensis*	4 to 10	M	T	M	I
American elm (hybrids)	*Ulmus* hybrids	4 to 6	T	T	T	T
American hazelnut	*Corylus americana*	4 to 9	I	T	M	I
American holly	*Ilex opaca*	5 to 6	M	T	M	I
American hophornbeam	*Ostrya virginiana*	3b to 9	I	T	M	I
American hornbeam	*Carpinus caroliniana*	3 to 9	M	T	M	I
American sycamore	*Platanus occidentalis*	3 to 9	T	T	M	I
Amur maackia	*Maackia amurensis*	3 to 7	I	T	T	M
Bald cypress	*Taxodium distichum*	5 to 10	T	T	T	I
Black cherry	*Prunus serotina*	3 to 9	I	T	M	I
Black tupelo	*Nyssa sylvatica*	4 to 9	T	T	T	M
Black walnut	*Juglans nigra*	5 to 8	I	T	T	T
Black willow	*Salix nigra*	3 to 5	T	T	I	I
Blackhaw	*Viburnum prunifolium*	3b	I	M	T	T
Boxelder	*Acer negundo*	3 to 9	T	T	T	I
Bur oak	*Quercus macrocarpa*	3 to 8	T	T	T	T
Butternut hickory	*Carya cordiformis*	4 to 9	T	T	T	I
Buttonbush	*Cephalanthus occidentalis*	5 to 9	T	T	M	I
Canada hemlock	*Tsuga canadensis*	3b to 7	I	T	M	I
Chestnut oak	*Quercus prinus*	4 to 8	I	T	T	I
Chinese fringetree	*Chionanthus retusus*	5 to 9	I	T	T	T
Common chokeberry	*Prunus virginiana*	2 to 6	I	T	T	M

Sun Exposure			Soil Components			Drought Tolerance	Flood Tolerance	Pest/ Disease Tolerance	Soil Compaction	Salt Tolerance	pH level
Full Sun	Partial Sun	Full Shade	Sand	Clay	Loam						
T	M	I	T	T	T	I	I	M	I	I	7.2 - 8.0
T	T	M	T	T	T	T	I	T	I	I	5.0 - 6.8
T	T	I	T	T	T	M	T	T	I	I	5.0 - 6.8
T	I	I	T	T	T	T	M	T	M	M	7.2 - 8.0
T	M	I	T	I	T	M	I	T	I	I	5.0 - 6.8
T	T	T	T	T	T	T	M	T	T	T	5.0 - 6.8
T	M	I	T	M	T	I	I	T	T	I	5.0 - 6.8
T	T	M	T	M	T	M	T	T	I	I	6.8 - 7.2
T	I	I	M	M	T	T	T	M	T	I	5.0 - 6.8
T	M	I	T	M	T	M	I	T	I	M	5.0 - 6.8
T	I	I	T	T	T	M	T	T	T	M	6.8 - 7.2
T	I	I	T	M	T	M	I	M	I	T	6.8 - 7.2
T	I	I	M	M	T	M	M	T	I	M	5.0 - 6.8
T	T	I	T	I	T	T	M	I	M	T	6.8 - 7.2
T	I	I	M	T	T	I	T	I	T	M	6.8 - 7.2
T	M	I	M	I	M	T	I	M	I	I	7.2 - 8.0
T	I	I	T	T	T	T	T	I	T	I	5.0 - 6.8
T	I	I	T	T	T	T	M	I	I	T	7.2 - 8.0
T	T	I	T	M	T	I	M	I	M	I	6.8 - 7.2
T	T	M	T	M	T	M	T	M		M	6.8 - 7.2
M	T	T	T	I	T	I	I	I	I	I	6.8 - 7.2
T	M	I	M	I	T	M	T	M			6.8 - 7.2
T	T	M	T	M	T	T	I	T	I		6.8 - 7.2
T	M	I	T	I	T	M	I	I	I	T	6.8 - 7.2

Chart 1. Tree Tolerance to Environmental Conditions - *continued*

Common Name	Scientific Name	Hardiness Zone	Soil Moisture			
			Saturated or wet	Moist, well drained	Periods of dry	Prolonged drought
Common hackberry	*Celtis occidentalis*	3 to 9	I	T	T	I
Common spicebush	*Lindera benzoin*	4 to 9	I	T	M	I
Crabapple	*Malus* spp.	3 to 8	I	T	M	M
Crimeon linden	*Tilia euchlora*	3 to 7	I	T	T	I
Douglas fir	*Pseudotsuga menziesii*	4 to 6	I	T	T	I
Eastern cottonwood	*Populus deltoides*	3 to 9	T	T	T	T
Eastern hemlock	*Tsuga canadensis*	3b to 7	I	T	T	I
Eastern hophornbeam	*Ostrya virginiana*	3b to 9	I	T	T	I
Eastern larch	*Larix laricina*	2 to 4	M	T	T	M
Eastern redbud	*Cercis canadensis*	4 to 9	I	T	T	I
Eastern redcedar	*Juniperus virginiana*	3b to 9	I	T	T	T
Eastern white pine	*Pinus strobus*	3 to 7	M	T	T	I
Elderberry	*Sambucus canadensis*	4 to 9	M	T	M	I
English oak	*Quercus robur*	4 to 8	I	T	T	T
European beech	*Fagus sylvatica*	4 to 7	I	T	T	I
European hornbeam	*Carpinus betulus*	5 to 7	M	T	T	I
Flowering dogwood	*Cornus florida*	5	I	T	T	I
Fringetree	*Chionanthus virginicus*	4 to 9	I	T	T	I
Ginkgo	*Ginkgo biloba* (male only)	4 to 8	I	T	T	T
Golden rain tree	*Koelreuteria paniculata*	5	M	T	T	T
Gray birch	*Betula populifolia*	3 to 6	M	T	T	I
Green ash	*Fraxinus pennsylvanica*	4 to 9	M	T	T	I
Hawthorn	*Crataegus viridis*	4 to 7	M	T	T	T
Hazel alder	*Alnus serrulata*	5 to 9	T	T	M	I

Sun Exposure			Soil Components			Drought Tolerance	Flood Tolerance	Pest/ Disease Tolerance	Soil Compaction	Salt Tolerance	pH level
Full Sun	Partial Sun	Full Shade	Sand	Clay	Loam						
T	M	I	T	I	T	I	M	I	M	T	7.2 - 8.0
T	T	I	T	M	T	I	T	T			7.2 - 8.0
T	M	I	T	M	T	M	M	I		M	6.8 - 7.2
T	I	I	T	I	T	M		M		I	7.2 - 8.0
T	M	I	M	M	T	I	M	I		I	6.8 - 7.2
T	M	I	T	T	T	T	T	I	T	T	6.8 - 7.2
M	T	T	T	M	T	I	I	I	I	I	5.0 - 6.8
T	M	I	T	I	T	I	I	T	I	I	7.2 - 8.0
T	M	I	M	M	T	T	M	I	T	T	5.0 - 6.8
T	M	M	T	I	T	I	M	T	M	M	6.8 - 7.2
T	M	I	T	M	T	T	I	M	I	T	7.2 - 8.0
T	M	I	T	M	M	M	I	I	I	I	5.0 - 6.8
T	T	I	M	M	T	I	T	I			6.8 - 7.2
T	I	I	T	I	T	T	I	I		M	7.2 - 8.0
T	M	I	T	I	T	M	I	M	I	I	5.0 - 6.8
T	M	I	M	M	T	M		T	I	I	7.2 - 8.0
M	T	T	T	I	T	M	T	I		I	6.8 - 7.2
T	T	M	T	M	T	I	I	T	I	I	5.0 - 6.8
T	M	I	T	I	T	M	T	T		T	6.8 - 7.2
T	M	I	T	M	T	T		T		T	7.2 - 8.0
T	I	I	T	T	T	M	T	I	M	T	6.8 - 7.2
T	M	I	T	M	T	M	T	I	T	M	6.8 - 7.2
T	I	I	T	M	T	T	M	I	T	M	7.2 - 8.0
T	I	I	T	T	T	I	T	T	T	I	6.8 - 7.2

Chart 1. Tree Tolerance to Environmental Conditions - *continued*

Common Name	Scientific Name	Hardiness Zone	Soil Moisture			
			Saturated or wet	Moist, well drained	Periods of dry	Prolonged drought
Hedge maple	*Acer campestre*	5 to 8	I	T	T	T
Highbush cranberry	*Viburnum trilobum*	2 to 7	I	T	M	I
Honeylocust	*Gleditsia triacanthos inermis*	4 to 9	I	T	T	T
Horsechestnut	*Aesculus × carnea*	5a	I	T	T	I
Hybrid elm	*Ulmus* hybrids	3 to 5	M	T	T	T
Japanese tree lilac	*Syringa reticulata*	3 to 7	I	T	T	T
Japanese zelkova	*Zelkova serrata*	5 to 8	I	T	T	I
Katsura tree	*Cercidiphyllum japonicum*	4 to 8	M	T	I	I
Laurel oak	*Quercus laurifolia*	6 to 9	T	T	T	I
Littleleaf linden	*Tilia cordata*	3b to 7	I	T	T	I
Loblolly pine	*Pinus taeda*	6 to 9	M	T	T	I
London planetree	*Platanus × acerifolia*	5 to 8	T	T	T	T
Mountain ash	*Sorbus* cultivars	4 to 6	I	T	T	I
Mountain-laurel	*Kalmia latifolia*	4 to 9	I	T	M	I
Mugo pine	*Pinus mugo*	3 to 7	I	T	M	I
Northern red oak	*Quercus rubra*	3b to 7	I	T	T	M
Nuttall oak	*Quercus nuttallii*	5 to 9	M	T	T	M
Overcup oak	*Quercus lyrata*	5 to 9	T	T	T	M
Paperbark birch	*Betula papyrifera*	2 to 6	M	T	T	I
Pawpaw	*Asimina triloba*	5 to 8	I	T	M	I
Persimmon	*Diospyros virginiana*	4 to 9	I	T	T	M
Pin oak	*Quercus palustris*	6 to 9	T	T	T	M
Pond cypress	*Taxodium ascendens*	5 to 9	T	T	T	M
Red (slippery) elm	*Ulmus rubra*	3 to 9	M	T	T	M
Red maple	*Acer rubrum*	3b to 9	T	T	T	I

Sun Exposure			Soil Components			Drought Tolerance	Flood Tolerance	Pest/ Disease Tolerance	Soil Compaction	Salt Tolerance	pH level
Full Sun	Partial Sun	Full Shade	Sand	Clay	Loam						
T	T	I	T	M	T	T		T	T	M	7.2 - 8.0
T	T	I	M	M	T	M	T	M	T	M	5.0 - 6.8
T	M	I	M	M	T	T	M	I	T	T	7.2 - 8.0
T	M	I		M	T	M		I	M	M	7.2 - 8.0
T	T	I	M	M	T	T	T	M	T	T	7.2 - 8.0
T	M	I	T	M	T	T	I	M		M	7.2 - 8.0
T	M	I	T	M	T	I		M	T	M	7.2 - 8.0
T	M	I	M	M	T	I		T	I	M	7.2 - 8.0
T	T	I	T	M	T	M		T	T	I	6.8 - 7.2
T	M	I	T	I	T	M	T	I	M	I	7.2 - 8.0
T	I	I	T	M	T	M	M	M	T	I	5.0 - 6.8
T	T	M	T	M	T	T	M	I	T	M	7.2 - 8.0
T	I	I	T	I	T	I	M	I	M		5.0 - 6.8
M	T	M	T	M	T	I	I	I			5.0 - 6.8
T	T	I	M	M	T	M	T	I	T	T	7.2 - 8.0
T	M	I	T	I	T	M	T	I	T	T	7.2 - 8.0
T	M	I	M	M	T	M	T	T	T	M	5.0 - 6.8
T	T	I	T	T	T	T	T	T	T		5.0 - 6.8
T	M	I	T	M	T	I	I	M	I	T	5.0 - 6.8
T	T	M	T	I	T	I	I	T	I	M	6.8 - 7.2
T	T	M	T	I	M	T	M	M	M	M	5.0 - 6.8
T	I	I	T	T	T	M		M	T	M	5.0 - 6.8
T	T	T	T	T	T	M	T	M		M	5.0 - 6.8
T	T	T	T	M	T	M	T	T	T		6.8 - 7.2
T	T	M	T	T	T	I	T	I	T	I	5.0 - 6.8

Chart 1. Tree Tolerance to Environmental Conditions - *continued*

Common Name	Scientific Name	Hardiness Zone	Soil Moisture			
			Saturated or wet	Moist, well drained	Periods of dry	Prolonged drought
Red-osier dogwood	*Cornus sericea*	2 to 7	T	T	M	I
River birch	*Betula nigra*	3b to 9	T	T	T	I
Sassafras	*Sassafras albidum*	4 to 9	I	T	T	T
Scarlet oak	*Quercus coccinea*	4 to 9	I	T	T	T
Serviceberry	*Amelanchier arborea*	4 to 9	I	T	T	I
Shagbark hickory	*Carya ovata*	4 to 8	M	T	T	T
Shingle oak	*Quercus imbricaria*	4 to 8	I	T	T	M
Shumard oak	*Quercus shumardii*	5 to 9	M	T	T	M
Silky dogwood	*Cornus amomum*	4 to 8	T	T	T	M
Silver linden	*Tilia tomentosa*	4 to 7	I	T	T	I
Silver maple	*Acer saccharinum*	3 to 9	T	T	T	I
Smooth sumac	*Rhus glabra*	3 to 9	I	M	T	T
Sourwood	*Oxydendrum arboreum*	5	I	T	T	I
Sugar maple	*Acer saccharum*	4 to 8	I	T	T	I
Sugarberry	*Celtis laevigata*	5 to 9	M	T	T	I
Swamp chestnut oak	*Quercus michauxii*	5 to 8	M	T	M	I
Swamp white oak	*Quercus bicolor*	4 to 8	M	T	T	I
Sweet-bay magnolia	*Magnolia virginiana*	5 to 9	T	T	M	I
Sweetgum	*Liquidambar styraciflua*	5 to 9	M	T	T	I
Trident maple	*Acer buergeranium*	5 to 8	I	T	T	M
Tulip tree	*Liriodendron tulipifera*	4 to 9	M	T	T	I
Water hickory	*Carya aquatica*	5 to 9	T	T	T	I
White ash	*Fraxinus americana*	4 to 9	M	T	T	I
White oak	*Quercus alba*	3b to 9	I	T	T	I
Willow oak	*Quercus phellos*	5 to 9	M	T	T	T
Winterberry	*Illex verticillata*	3 to 5	T	T	T	I
Witch hazel	*Hammamelis virginiana*	3b to 8	I	T	T	I

Sun Exposure			Soil Components			Drought Tolerance	Flood Tolerance	Pest/ Disease Tolerance	Soil Compaction	Salt Tolerance	pH level
Full Sun	Partial Sun	Full Shade	Sand	Clay	Loam						
T	T	I	M	T	T	M	T	M	T	I	6.8 - 7.2
T	M	I	T	T	T	I	M	M	T	I	5.0 - 6.8
T	T	I	T	I	T	T	I	T	T	M	5.0 - 6.8
T	M	I	T	I	M	T	I	T	I	M	5.0 - 6.8
T	T	M	T	I	T	I	I	T	I	I	6.8 - 7.2
T	T	M	T	M	T	T	I	T	M	I	5.0 - 6.8
T	M	I	T	M	T	M	M	T	M	M	5.0 - 6.8
T	M	I	T	I	T	M		T	T	M	7.2 - 8.0
M	T	M	T	I	T	M	T	T	T	I	5.0 - 6.8
T	M	I	T	I	T		T		M	M	7.2 - 8.0
T	M	I	T	T	T	I	T	I	T	M	5.0 - 6.8
T	M	I	T	M	T	T	T	T	I	T	6.8 - 7.2
T	T	M	T	I	T	M	I	T	I	M	6.8 - 7.2
T	T	M	T	I	T	I	I	I	I	I	6.8 - 7.2
T	M	I	T	M	T	M	T	M	T	T	6.8 - 7.2
T	M	M	M	M	T	I	M	M	T		5.0 - 6.8
T	T		M	T	T	I	M	T	T		6.8 - 7.2
T	T	M	T	T	T	I	T	T	T		5.0 - 6.8
T	M	I	T	T	T	I	T	T	T	M	6.8 - 7.2
T	I	I	T	I	T	M		T	M	M	5.0 - 6.8
T	T	M	T	M	T	I	I	T	I	I	5.0 - 6.8
T	T	I	T	M	T	M	T	T	T	I	6.8 - 7.2
T	T	M	T	M	T	I	M	I	M	M	6.8 - 7.2
T	T	M	T	T	T	M	I	I	I	T	5.0 - 6.8
T	T	M	T	T	T	T	M	I	T	I	6.8 - 7.2
T	T	M	T	T	T	M	I	M	T	I	5.0 - 6.8
I	M	T	M	M	T	I	I	T	I	I	5.0 - 6.8

Definitions Used in Chart 2

Height – Tree height is measured in feet from the base of the tree to the tip of the canopy.

Canopy Spread – The width is measured as the diameter of the canopy in feet.

Growth Rate – Slow growth is defined as having an annual leader increment of 12 inches or less. Medium growth is defined as having an annual leader increment between 12 to 24 inches. Fast growth is defined as having the potential to produce 24 or more inches of annual leader increment.

Form/Habit – A description of the tree's overall shape or outline and its structure, when mature.

Root Structure – Shallow lateral roots form a fibrous mat up to 4 feet deep and from 1½ to 3 times the reach of the canopy. Deep lateral roots are extensive underground systems that grow more than 4 feet underground, with the same reach as shallow lateral roots; they are not recommended for use near perforated drainage pipes and irrigation systems. The taproot is the single thick root that grows straight into the soil to a depth of 15 feet or more. Plants with a sizeable taproot are considerably more tolerant to drought because the taproot penetrates to a depth where water is available.

Native – In the context of this chart, native species are those that are indigenous to the Mid-Atlantic or Northeastern Region of the United States. The native species in the chart have evolved in these geographic regions and thus are adapted to the historic range of climatic, physical, and biological factors associated with these regions. A few of the trees in the chart, while native, are not native to the geographic region of interest and are so noted (e.g., native to western or southeastern United States). Lastly, there are species that are not native or are cultivars. Non-native species were introduced to the United States from other parts of the world, while cultivars are a by-product of breeding species for certain desired characteristics.

Fruit – Describes the type of fruit and, in some cases, also lists fruit color or size. Fruit types are generically presented. Appeal to wildlife (e.g., acorns of oak species, berries) and significance of limb, bark, or fruit litter should also be considered (see the list of Sources for this appendix for more information).

Seasonal Foliage Cover – Describes the plants leaf color during the growing season and notes any color changes for autumn.

Flower – Information about when plants bloom and flower color. There are also subjective notes to document if the flower is visually appealing ("showy") or visually insignificant ("not showy").

Chart 2. Tree Characteristics

Common Name	Scientific Name	Height (ft.)	Canopy Spread (ft.)	Growth Rate	Form/Habit
American basswood	*Tilia americana*	50 to 80	35 to 50	medium	youth: pyramidal, mature: oval & rounded
American beech	*Fagus grandifolia*	50 to 75	40 to 60	slow	oval, pyramidal, symmetrical
American elder	*Sambucus canadensis*	8 to 12	6 to 10	fast	upright vase canopy, multiple stems
American elm (hybrids)	*Ulmus* hybrids	50 to 70	40 to 60	fast	varies with cultivar
American hazelnut	*Corylus americana*	8 to 15	6 to 10	medium	straight, spreading, ascending branches
American holly	*Ilex opaca*	40 to 50	15 to 25	slow	pyramidal, symmetrical
American hophornbeam	*Ostrya virginiana*	30 to 50	20 to 30	slow	oval to rounded, horizontal drooping branches
American hornbeam	*Carpinus caroliniana*	30 to 50	20 to 35	slow	horizontal, pyramidal to vase, symmetrical
American sycamore	*Platanus occidentalis*	75 to 90	50 to70	fast	rounded, spreading, pyramidal
Amur maackia	*Maackia amurensis*	20 to 35	15 to 25	slow	rounded, vase shape, symmetrical
Bald cypress	*Taxodium distichum*	50 to 70	20 to 40	medium	pyramidal, buttressed trunk at base
Black cherry	*Prunus serotina*	60 to 90	35 to 50	fast	oval
Black tupelo	*Nyssa sylvatica*	30 to 60	20 to 40	medium	pyramidal or irregular-round, dense branching
Black walnut	*Juglans nigra*	70 to 90	60 to100	medium	open, rounded
Black willow	*Salix nigra*	60 to 100	20 to 35	fast	straight trunk, upright branches, narrow
Blackhaw	*Viburnum prunifolium*	15 to 20	10	medium	small tree or shrub, short trunk, rounded
Boxelder	*Acer negundo*	30 to 50	40 to 60	fast	rounded, multi-stemmed branching
Bur oak	*Quercus macrocarpa*	60 to 80	60 to 90	slow	large trunk, broadly rounded, open

Root Structure	Native to U.S.	Fruit	Seasonal Foliage Color		Flower	
			Summer	**Fall**	**Blooming Season**	**Characteristics**
deep lateral	native	nutlet	green	yellow	summer	light yellow, fragrant, not showy
shallow lateral	native	nut	green	copper	spring	yellow, not showy
shallow lateral	native	berry, purple-black	green	yellow	summer	white, showy
shallow & deep lateral	native	samara, disc-shaped	green	yellow	spring	green, not showy
shallow lateral	native	nut	green	brown	spring	white on long stalks, showy
shallow lateral	native	berry, red	green	green	spring	white, not showy
deep lateral & taproot	native	pods, small, greenish-white inflated in hanging clusters	dark green	yellow	spring (female), winter (male)	dioecious, male flower is showy
deep lateral	native	**nutlet**	**green**	**orange, red, yellow**	**spring**	**orange, yellow, not showy**
shallow lateral	native	syncarp, round, bristly	green	yellow, not showy	spring	red, not showy
shallow lateral	not native	pod	green	green, not showy	summer	white, showy
shallow lateral	native	cone, small	green	orange-brown	spring	brown, not showy
deep lateral, taproot	native	cherry, small, dark red, nearly black, produces fruit litter	dark green	yellow-red	spring	white, showy
taproot	native	berry, bluish, small, produces fruit litter	green	orange-red, variable	spring with leaves	green-white, not showy
taproot	native	seed housed in green or brown 1-2" husk, produces fruit litter	green	yellow	spring	green, not showy
shallow lateral	native	capsule, small, with cottony seeds	green	yellow-brown	spring	yellow, not showy
deep lateral	native	berry, blue-black	green	red, shiny	spring	white, showy, small
deep lateral	native	samara, profuse, produces fruit litter	light green	yellow-green to brown	spring	yellow-green, not showy
taproot	native	acorn, fringed cap, produces fruit litter	dark green	dull yellow-green	spring, with leaves	yellow, not showy

Chart 2. Tree Characteristics — *continued*

Common Name	Scientific Name	Height (ft.)	Canopy Spread (ft.)	Growth Rate	Form/Habit
Butternut hickory	*Carya cordiformis*	60 to 80	30 to 40	slow	tall trunk, broad, rounded
Buttonbush	*Cephalanthus occidentalis*	6 to 12	6 to 10	slow	shrub, rounded, loosely branched
Canada hemlock	*Tsuga canadensis*	40 to 70	25 to 35	medium	pyramidal, branches pendulous
Chestnut oak	*Quercus prinus*	60 to 70	30 to 50	medium	rounded and relatively dense branching
Chinese fringetree	*Chionanthus retusus*	15 to 25	10 to 25	slow	small tree, rounded, multi-stemmed
Common chokeberry	*Prunus virginiana*	20 to 30	18 to 25	fast	oval to upright small tree, spreading
Common hackberry	*Celtis occidentalis*	40 to 60	60 to 70	medium	rounded with pendulous branches
Common spicebush	*Lindera benzoin*	6 to 12	6 to 10	slow	rounded shrub
Crabapple	*Malus* spp.	16 to 30	8 to 35	medium	rounded, upright to weeping, varies
Crimeon linden	*Tilia euchlora*	40 to 60	20 to 30	medium	pyramidal to rounded, densely branched
Douglas fir	*Pseudotsuga menziesii*	40 to 80	12 to 20	medium	pyramidal crown, densely branched
Eastern cottonwood	*Populus deltoides*	75 to 100	50 to 75	fast	vase-shaped, spreading branches
Eastern hemlock	*Tsuga canadensis*	40 to 70	25 to 35	medium	pyramidal, branches pendulous
Eastern hophornbeam	*Ostrya virginiana*	30 to 50	20 to 30	slow	rounded, horizontal, drooping branches
Eastern larch	*Larix laricina*	40 to 80	15 to 30	medium	pyramidal, open, drooping branches
Eastern redbud	*Cercis canadensis*	20 to 30	25 to 35	medium	spreading, open branching
Eastern redcedar	*Juniperus virginiana*	40 to 50	8 to 20	slow	densely pyramidal

Root Structure	Native to U.S.	Fruit	Seasonal Foliage Color		Flower	
			Summer	**Fall**	**Blooming Season**	**Characteristics**
taproot	native	nut, produces fruit litter	yellow-green	yellow-gold	spring, with leaves	green, not showy
lateral	native	nutlets	dark green	evergreen	summer	white, showy
shallow lateral	native	cone	dark green	evergreen	summer	yellow-green, not showy
lateral	native	acorn, produces fruit litter	yellow-green	orange-yellow to yellow brown	spring	yellow-green, not showy
lateral	not native	berry, blue	green, leathery	yellow	spring	white, showy, fragrant
shallow lateral	native	berry, red to dark purple	dark green	yellow	spring	white, showy
deep lateral	native	berry, orange-red	green	yellow, yellow-green	spring, with leaves	not showy
lateral	native	berry, scarlett	light green, fragrant	yellow to gold	spring, before leaves	dioecious, yellow-green, small, somewhat showy in early spring
lateral	varies	berry, red, small, produces fruit litter	varies	varies	spring	white to pink, showy, fragrant
lateral	not native	nutlets, small	dark green	green to yellow-green	summer	yellow fragrant, showy
lateral	not native to Mid-Atlantic or North-east	cone, pendulous	green	evergreen	summer	not showy
shallow lateral	native	capsule, opens with cottony seeds	medium green	yellow	spring, before leaves	greenish catkins, not showy
shallow lateral	native	cone, small	dark green	evergreen	summer	not showy
deep lateral, taproot	native	pods, greenish-white in tight clusters	dark green	yellow	spring/ winter	not showy
shallow lateral	native	cone	blue-green	yellow	spring	not showy
shallow lateral	native	pods	early leaves purplish then green	yellow to golden	spring, before leaves	purple-pink, showy
taproot	native	cones, greenish blue, glaucous	sage green	evergreen	winter to spring	not showy, dioecious

Chart 2. Tree Characteristics — *continued*

Common Name	Scientific Name	Height (ft.)	Canopy Spread (ft.)	Growth Rate	Form/Habit
Eastern white pine	*Pinus strobus*	50 to 80	20 to 40	medium	broadly pyramidal, horizontal branches
Elderberry	*Sambucus canadensis*	5 to 12	4 to 6	fast	shrub, multiple stemmed, spreading branches
English oak	*Quercus robur*	40 to 60	40 to 60	slow	massive tree with short trunk, broadly round
European beech	*Fagus sylvatica*	50 to 60	35 to 45	slow	pyramidal to rounded, low branches
European hornbeam	*Carpinus betulus*	40 to 60	30 to 40	slow	rounded
Flowering dogwood	*Cornus florida*	20 to 30	20 to 30	medium	rounded, low branching
Fringetree	*Chionanthus virginicus*	12 to 15	10 to 15	slow	shrub, large,open spreading habit
Ginkgo	*Ginkgo biloba* (male only)	50 to 60	30 to 40	slow	pyramidal, open, wide-spreading branches
Golden rain tree	*Koelreuteria paniculata*	30 to 40	30 to 40	medium	irregular rounded, open
Gray birch	*Betula populifolia*	40 to 50	30 to 40	medium	pyramidal
Green ash	*Fraxinus pennsylvanica*	40 to 60	30 to 50	fast	rounded
Hawthorn	*Crataegus viridis*	20 to 25	12 to 35	slow	rounded to vase-shaped
Hazel alder	*Alnus serrulata*	6 to 20	4 to 15	fast	small tree, multi-stemmed
Hedge maple	*Acer campestre*	25 to 35	25 to 35	slow	rounded, low branching
Highbush cranberry	*Viburnum trilobum*	8 to 12	8 to 12	medium	large shrub, upright spreading, multi-stemmed
Honeylocust	*Gleditsia triacanthos inermis*	40 to 80	30 to 70	fast	rounded, spreading
Horsechestnut (red)	*Aesculus × carnea*	35 to 50	30 to 45	slow	rounded, dense branching
Hybrid elm	*Ulmus* hybrids	50 to 70	40 to 60	varies with cultivar	varies with cultivar
Japanese tree lilac	*Syringa reticulata*	20 to 25	15 to 20	slow	oval, spreading, densely branched

Root Structure	Native to U.S.	Fruit	Seasonal Foliage Color		Flower	
			Summer	**Fall**	**Blooming Season**	**Characteristics**
deep lateral	native	cones, pendant	bluish green,	evergreen	summer	not showy
lateral	native	berry, blue in clusters	dark green	yellow-green	summer	white to cream, showy
lateral	not native	acorn	dark green	brown	spring with leaves	not showy
shallow lateral	not native	husk, small, covered with bristles	dark green	red to gold	spring with leaves	not showy
lateral	not native	nutlets in pendulous cluster	dark green	yellow to yellow-green	spring	not showy
shallow	native	berry, red cluster	dark green	red to red-purple	spring	white, showy
deep lateral	native	berry, blue	green	yellow-brown to golden	spring	white, showy, fragrant
lateral	not native	not applicable to male trees	green	yellow	spring	not showy, dioecious
deep lateral	not native	capsule, green to brown	green to blue-green	yellow	summer	yellow clusters, showy
shallow lateral	native	nutlet, small	dark green	yellow	spring	catkins, not showy
shallow lateral	native	samara-like	green	yellow	spring with leaves	not showy, dioecious, flower litter problem
shallow lateral	native	berry, red	green	scarlet to purple	spring	white clusters, showy
shallow lateral	native	cone-like, small	green	yellow-brown	winter to early spring	yellow-brown catkins, in late winter
shallow lateral	not native	samara	dark green	yellow	spring	green, not showy
shallow lateral	native, upper North-east	berry, red	dark green	yellow to red-purple	spring	white, showy
shallow lateral, taproot	natural-ized	pod, long brown, produces fruit litter	light green	yellow-brown	summer	not showy
shallow lateral	not native	nut, glossy, somewhat prickly	dark green	yellow-brown	spring	pink to red clusters, showy
shallow lateral	not native	samara, small	green	yellow	late winter to spring	greenish-red, not showy
lateral	not native	capsule	dark green	yellow-brown	summer	cream, showy, fragrant

Chart 2. Tree Characteristics — *continued*

Common Name	Scientific Name	Height (ft.)	Canopy Spread (ft.)	Growth Rate	Form/Habit
Japanese zelkova	***Zelkova serrata***	50 to 80	50 to 75	medium	vase-shaped, spreading branches
Katsura tree	***Cercidiphyllum japonicum***	40 to 60	25 to 60	fast	rounded
Laurel oak	***Quercus laurifolia***	60 to 70	35 to 45	fast	oval, densely branched
Littleleaf linden	***Tilia cordata***	50 to 70	30 to 50	medium	oval to rounded, densely branched
Loblolly pine	***Pinus taeda***	60 to 90	30	fast	oval to rounded, branches horizontal
London planetree	***Platanus × acerifolia***	70 to 100	65 to 80	medium	open and spreading
Mountain ash	***Sorbus*** cultivars	15 to 25	15 to 25	medium	varies with cultivar
Mountain-laurel	***Kalmia latifolia***	3 to 15	3 to 15	slow	large shrub, symmetrical
Mugo pine	***Pinus mugo***	15 to 20	20 to 25	slow	prostrate or pyramidal
Northern red oak	***Quercus rubra***	40 to 60	40 to 60	medium	rounded, open
Nuttall oak	***Quercus nuttallii***	60 to 80	40 to 50	fast	oval, open
Overcup oak	***Quercus lyrata***	40 to 60	35 to 60	medium	rounded
Paperbark birch	***Betula papyrifera***	50 to 70	25 to 50	medium	rounded, low branching
Pawpaw	***Asimina triloba***	15 to 20	15 to 20	medium	shrub/small tree, rounded crown
Persimmon	***Diospyros virginiana***	30 to 60	20 to 35	slow	rounded crown
Pin oak	***Quercus palustris***	50 to 70	40 to 50	medium	oval-pyramidal
Pond cypress	***Taxodium ascendens***	70 to 80	15 to 20	slow	conical
Red (slippery) elm	***Ulmus rubra***	50 to 80	40 to 60	medium	vase-shaped
Red maple	***Acer rubrum***	35 to 60	30 to 70	medium	varies with cultivar

Root Structure	Native to U.S.	Fruit	Seasonal Foliage Color		Flower	
			Summer	**Fall**	**Blooming Season**	**Characteristics**
lateral	not native	berry, small	green	yellow-orange to red	spring	not showy
shallow lateral	not native	pods, small in clusters	bluish-green	yellow to orange	spring before leaves	not showy
lateral	native	acorn	green	yellow	spring	not showy
deep lateral	not native	nutlet	dark green	yellow green to yellow	summer	yellow pendant clusters, fragrant, showy
shallow taproot, lateral	native	cone	green	evergreen	summer	not showy
shallow	not native	syncarp, bristly, rounded, produces fruit litter	green	yellow-brown	spring	not showy
lateral	not native	berry, orange-red	green	varies	spring	white clusters, showy
lateral	native	capsule	dark green	evergreen	spring	white to deep rose, showy
deep lateral	not native	cone	yellow-green	evergreen	summer	not showy
lateral, short taproot	native	acorn, produces fruit litter	green to blue-green	brown	spring with leaves	not showy
shallow lateral	native to central US	acorn, produces slight fruit litter	green	red	spring	not showy
lateral	native	acorn, produces fruit litter	dark green	yellow-brown	spring with leaves	not showy
lateral	native	nutlet	dark green	yellow	spring before leaves	not showy
deep lateral	native	berry, yellow turning brown/ black, produces fruit litter	green	yellow to yellow-green	spring with leaves	purple, not showy
taproot	native	berry, yellow to pale orange	dark green	yellow-green to red-purple	spring	white, fragrant, somewhat showy
shallow lateral	native	acorn, produces fruit litter	dark green	bronze to red	spring	not showy
taproot	native to South-east	cone	green	orange-brown	spring	not showy
lateral	native	samara	dark green	yellow	spring before leaves	not showy
shallow lateral	native	samara	green	yellow, orange, red	spring before leaves	red, showy

Chart 2. Tree Characteristics — *continued*

Common Name	Scientific Name	Height (ft.)	Canopy Spread (ft.)	Growth Rate	Form/Habit
Red-osier dogwood	*Cornus sericea*	7 to 9	7 to 10	fast	broad-spreading shrub
River birch	*Betula nigra*	40 to 50	30 to 40	fast	pyramidal to oval, multi-stemmed
Sassafras	*Sassafras albidum*	30 to 60	25 to 40	medium	rounded
Scarlet oak	*Quercus coccinea*	70 to 75	40 to 50	medium	rounded
Serviceberry	*Amelanchier arborea*	20 to 30	15 to 25	medium	oval, multi-stemmed
Shagbark hickory	*Carya ovata*	60 to 80	25 to 35	slow	oblong
Shingle oak	*Quercus imbricaria*	60 to 70	40 to 50	slow	rounded, open
Shumard oak	*Quercus shumardii*	60 to 80	45 to 65	medium	rounded
Silky dogwood	*Cornus amomum*	6 to 10	6 to 10	medium	shrub, rounded, multistemmed
Silver linden	*Tilia tomentosa*	50 to 70	35 to 55	medium	pyramidal, densely branched
Silver maple	*Acer saccharinum*	50 to 70	30 to 50	fast	rounded, spreading
Smooth sumac	*Rhus glabra*	10 to 15	10 to 15	fast	shrub/small tree, spreading
Sourwood	*Oxydendrum arboreum*	40 to 60	30 to 35	slow	varies
Sugar maple	*Acer saccharum*	45 to 50	35 to 40	slow	rounded
Sugarberry	*Celtis laevigata*	60 to 80	60 to 80	medium	rounded, spreading branches
Swamp chestnut oak	*Quercus michauxii*	60 to 70	30 to 50	medium	rounded
Swamp white oak	*Quercus bicolor*	50 to 60	50 to 60	slow	broad, open

Root Structure	Native to U.S.	Fruit	Seasonal Foliage Color		Flower	
			Summer	**Fall**	**Blooming Season**	**Characteristics**
shallow lateral	native	berry, white	green	purple to red	spring	white, showy
shallow lateral	native	nutlet	green	yellow	spring before leaves	not showy
taproot	native	berry, dark blue	green	yellow to orange to red	spring	yellow, showy
taproot	native	acorn, produces some fruit litter	dark green	scarlet	spring	not showy
shallow lateral	native	samara	green	varies	spring	greenish-yellow, showy
taproot	native	nuts encased in hard-shelled husk, produces fruit litter	yellow-green	yellow to golden brown	spring with leaves	not showy
taproot	native	acorn, produces fruit litter	dark green	red to scarlet	spring with leaves	not showy
taproot	native	acorn, produces some fruit litter	dark green	yellow to red	spring with leaves	not showy
shallow lateral	native	berry, blue	dark green	green to reddish purple	spring	yellowish-white, showy
shallow lateral	not native	nutlet	dark green	green-yellow to yellow	summer	yellow, clusters, fragrant, showy
shallow lateral	native to South-east	samara	green, silvery	yellow-brown	spring	greenish, yellow to red, some showy
shallow lateral	native	berry, deep red, cluster	dark green	yellow to orange-red	summer	green-yellow, not showy
deep lateral	native	capsule, brown	dark green	yellow, red to purple	summer	white, fragrant, showy
shallow lateral	native	samara	green	yellow, orange to red	spring before leaves	yellow clusters, somewhat showy
shallow lateral	native	berry, orange-red to blue-black, produces short-term fruit litter	green	yellow	spring	not showy
lateral	native	acorn, produces fruit litter	green	brown to dark red	spring	not showy
shallow lateral	native	acorn, produces some fruit litter	dark green	yellow, red-purple	spring	not showy

Chart 2. Tree Characteristics — *continued*

Common Name	Scientific Name	Height (ft.)	Canopy Spread (ft.)	Growth Rate	Form/Habit
Sweet-bay magnolia	*Magnolia virginiana*	10 to 20	10 to 20	medium	shrub/small tree, loose, open
Sweetgum	*Liquidambar styraciflua*	50 to 75	40 to 65	medium	rounded
Trident maple	*Acer buergeranium*	20 to 25	20 to 25	slow	rounded, low branching, bonsai potential
Tulip tree	*Liriodendron tulipifera*	70 to 90	35 to 50	fast	oval crown
Water hickory	*Carya aquatica*	50 to 65	30 to 40	fast	oval
White ash	*Fraxinus americana*	50 to 70	40 to 60	medium	rounded
White oak	*Quercus alba*	60 to 100	50 to 90	slow	broad rounded, spreading
Willow oak	*Quercus phellos*	40 to 60	30 to 60	medium	rounded
Winterberry	*Illex verticillata*	6 to 10	6 to 10	slow	shrub, rounded, densely branched
Witch hazel	*Hammamelis virginiana*	10 to 12	12 to 18	medium	shrub, irregular, spreading branches

Root Structure	Native to U.S.	Fruit	Seasonal Foliage Color		Flower	
			Summer	**Fall**	**Blooming Season**	**Characteristics**
shallow lateral	native	aggregate of red berry-like fruits	dark green	yellow to yellow-brown, semi-evergreen	spring, ongoing	creamy white, fragrant, showy
lateral, taproot	native	aggregate of stiff capsules, produces fruit litter	green	yellow, orange, red, purple	spring with leaves	not showy
lateral	not native	samara	dark green	yello, orange, red	spring	not showy
shallow and deep lateral	native	cluster of woody samaras	green	yellow	spring	pale green with orange, showy
taproot	native to South-east	seeds in a thin husk, produces fruit litter	dark green	yellow to golden brown	spring before leaves	not showy
shallow lateral	native	samara	dark green	yellow to purple	spring	not showy
taproot	native	acorn, produces some fruit litter	gray green	red to scarlet	spring	not showy
shallow lateral	native	acorn, produces some fruit litter	dark green	yellow, brown, red	spring with leaves	not showy
shallow lateral	native	berry, red	green	yellow	spring	white clusters, showy
deep lateral	native	capsule	green	yellow	summer into fall	yellow, somewhat showy

Appendix C. Urban Tree Planting Budget Worksheet

1. General Site Information Planting Site ID: _________ Planting Site Location: Owner Name and Contact Information: Proposed Planting Date: ________ Worksheet Completed by: _______			
2. Site Preparation *Trash cleanup, invasive plant removal, or soil amendments*			
Type	*Number of units*	*Unit cost*	*Total cost*
		$ $ $	$ $ $
			Subtotal $_______________
3. Plant Materials *Species, type, size and number*			
Materials	*Number*	*Unit cost*	*Total cost*
		$ $ $ $ $ $ $	$ $ $ $ $ $ $
			Subtotal $_______________

4. Equipment and Supplies *Heavy equipment rental or purchase, supplies (e.g., shovels, gloves, stakes, tree shelters)*			
Type	*Number*	*Unit cost*	*Total cost*
		$ $ $ $	$ $ $ $
			Subtotal $______________

5. Maintenance *Units costs (non-labor) related to maintenance (e.g., mulch)*			
Type	*Number of units*	*Unit cost*	*Total cost*
		$ $ $ $	$ $ $ $
			Subtotal $______________

6. Labor *Includes labor for all stages of the planting project (site preparation, planting, and maintenance)*			
Type	*Number hours*	*Rate*	*Total cost*
		$ $ $ $	$ $ $ $
			Subtotal $______________

7. Total Cost	$____________________

References

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