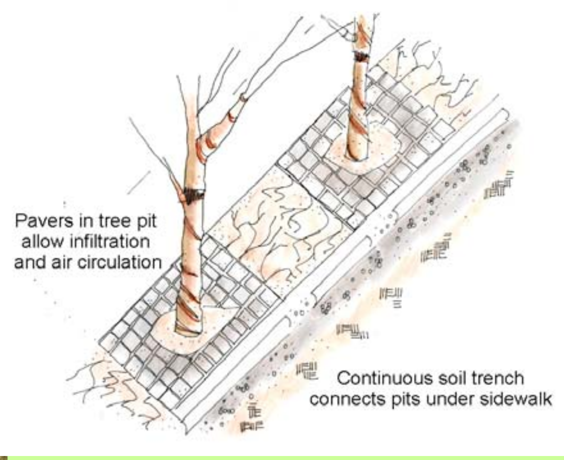
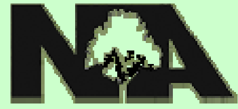


Center for Watershed Protection

URBAN WATERSHED FORESTRY MANUAL

Part 3: Urban Tree Planting Guide



March 2006

URBAN WATERSHED FORESTRY MANUAL
Part 3: Urban Tree Planting Guide

Prepared by:

Karen Cappiella, Tom Schueler, Jennifer Tomlinson, and Tiffany Wright
Center for Watershed Protection
8390 Main Street, Second Floor
Ellicott City, MD 21043
www.cwp.org
www.stormwatercenter.net

Prepared for:

USDA Forest Service, Northeastern Area State and Private Forestry
11 Campus Boulevard, Suite 200
Newtown Square, PA 19073
www.na.fs.fed.us
USDA is an equal opportunity provider and employer

March 2006

ABOUT THIS MANUAL SERIES

This is the third in a three-part series of manuals 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 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) with funding from the USDA Forest Service through a grant from the National Fish and Wildlife Foundation (NFWF), project #2004-0001-001, and 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 Al Todd of the USDA Forest Service. Thanks go also to Roderick Salguaro and Lisa D. Hoover of the USDA Forest Service for their assistance compiling and reviewing the Urban Tree Database.
Thanks go to the following reviewers of Part 3:

- Al Todd, USDA Forest Service
- James Urban, FASLA, 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
- Miles Barnard, Southfork Studios
- Ken Belt, USDA Forest Service
- 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
- Jim 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

TABLE OF CONTENTS

List of Tables ____ vii

List of Figures ____ viii

List of Text Boxes ____ ix

CHAPTER 1: INTRODUCTION ____ 1

CHAPTER 2: URBAN REFORESTATION SITE ASSESSMENT ____ 7

2.1 General Site Information ____ 9
- Location ____ 9
- Property Owner ____ 9
- Current Land Use ____ 9

2.2 Climate ____ 9
- USDA Plant Hardiness Zone ____ 9
- Sunlight Exposure ____ 10
- Micro-Climate Features ____ 10

2.3 Topography ____ 10
- Steep Slopes ____ 10
- Low-Lying Areas ____ 10

2.4 Vegetation ____ 10
- Regional Forest Association ____ 10
- Current Vegetative Cover ____ 11
- Adjacent Vegetative Cover ____ 11

2.5 Soils ____ 11
- Texture ____ 11
- Drainage ____ 12
- Compaction ____ 12
- pH ____ 12
- Other Soil Features ____ 13
- Soil Chemistry ____ 13

2.6 Hydrology ____ 13
- Site Hydrology ____ 13
- Storm Water Runoff to Planting Site ____ 13
- Contributing Flow Length ____ 14
- Floodplain Connection ____ 14

2.7 Potential Planting Conflicts 15
Space Limitations 15
Other Limiting Factors 15
Local Ordinance Setbacks 16

2.8 Planting and Maintenance Logistics 16
Site Access 16
Water Source 17
Party Responsible for Maintenance 17

2.9 Site Sketch 17

CHAPTER 3: BASIC PLANTING DESIGN 19

3.1 Plant Species 19
Factors Influencing Species Selection 19
The Importance of Diversity 21

3.2 Plant Materials 21

3.3 Plant Spacing and Density 23

3.4 Planting Plan 25

CHAPTER 4: SPECIAL CONSIDERATIONS FOR URBAN TREE PLANTING 29

4.1 Calculating Soil Volume 29

4.2 Evaluating Storm Water Runoff 31
Under-Capacity Sites 32
At-Capacity Sites 33
Over-Capacity Sites 35

4.3 Reducing Conflicts Between Trees and Infrastructure 37
Utilities 38
Pavement 40
Structures 44
Lighting and Signs 45
Trails 45

4.4 Protecting Trees from Human and Animal Impacts 45
Beaver 46
Deer 46
Human Impacts 48

CHAPTER 5: SITE PREPARATION TECHNIQUES 51

5.1 Trash and Debris Cleanup 51
Evaluating the Site 51
Planning and Implementing the Cleanup 52
Costs of Trash and Debris Cleanup 53

5.2 Invasive Plant Control 53
Evaluating the Site 54
Selecting and Implementing Invasive Plant Control Methods 55
Costs of Invasive Plant Control 59

5.3 Soil Amendments 59
Evaluating Urban Soils 61
Planning and Implementing Soil Amendments 62
Costs of Soil Amendments 64

CHAPTER 6: PLANTING, INSPECTION, AND MAINTENANCE TECHNIQUES 65

6.1 Obtaining and Storing Plant Materials 65
Obtaining Plant Materials 65
Storing Plant Materials 66

6.2 Planting Techniques 67
Planting Techniques for Various Plant Materials 67
Planting on Steep Slopes 69
Encouraging Natural Regeneration 71

6.3 Post Planting Tree Protection 73
Mulch 73
Stakes 74
Tree Shelters 74
Signage 74

6.4 Tree Inspection and Maintenance Techniques 75
Inspection 76
Watering 77
Pruning 78
Weed Control 78
Integrated Pest Management 79

REFERENCES 81

Appendix A. Urban Reforestation Site Assessment (URSA) Field Sheet A-1

Appendix B. Urban Tree Selection Guide B-1

Appendix C. Urban Tree Planting Budget Worksheet C-1

LIST OF TABLES

Table 1. Special Considerations and Site Preparation for Planting Trees in Various Urban Locations 2
Table 2. Special Considerations for Planting Trees in Storm Water Treatment Practices 3
Table 3. Resources Used in Creating the URSA 8
Table 4. Environmental Conditions Influencing Species Selection 20
Table 5. Advantages and Disadvantages of Various Plant Materials 22
Table 6. Example Planting Densities for Various Size Trees 24
Table 7. Estimated Units Costs for Plant Materials and Planting Supplies 26
Table 8. Storm Water Treatment Capacity Conditions at Potential Planting Sites 32
Table 9. Methods to Reduce Conflicts Between Trees and Infrastructure 38
Table 10. Recommended Minimum Setbacks for Overhead Wires 40
Table 11. Alternative Sidewalk Design Methods 43
Table 12. Alternative Construction Materials to Reduce Tree/Sidewalk Conflicts 44
Table 13. Factors to Evaluate at an Illegal Dumping Site 52
Table 14. Invasive Plant Indexing System 55
Table 15. Comparison of Invasive Plant Control Methods 56
Table 16. Recommended Corrective Measures for Urban Soils 61
Table 17. Equipment for Urban Soil Amendment Projects 63
Table 18. Sources of Plant Materials 66
Table 19. Tree Planting Techniques 67
Table 20. Advantages and Disadvantages of Natural Regeneration 71
Table 21. Example Inspection and Maintenance Schedule 76

LIST OF FIGURES

Figure 1. A typical urban planting site has many limiting factors 1
Figure 2. Sample site sketch for an URSA 18
Figure 3. Types of plant materials: bare root, container grown, and balled and burlapped 22
Figure 4. Example planting plan for an urban reforestation site 26
Figure 5. Typical urban tree pits only provide about 50 cubic feet of soil 29
Figure 6. Soil volume required for various size trees 30
Figure 7. Urban trees in raised planters receive very little water from rainfall or runoff 31

Figure 8. This under-capacity site does not receive any storm water runoff ____ 32
Figure 9. This at-capacity site receives rooftop runoff from adjacent townhomes ____ 34
Figure 10. Forested filter strip profile ____ 34
Figure 11. Forested filter strip plan view ____ 35
Figure 12. Concentrated flow at this over-capacity site must be dealt with prior to planting ____ 36
Figure 13. Bioretention facility with trees ____ 37
Figure 14. Trees may conflict with infrastructure above ground, at the surface, below ground or in the root zone ____ 38
Figure 15. Bradford pears pruned extensively to reduce conflict with overhead wires ____ 40
Figure 16. Tree roots cause adjacent pavement to crack ____ 42
Figure 17. Curving sidewalk allows space for trees ____ 43
Figure 18. Structural soils used in a street tree application ____ 45
Figure 19. Trees planted in narrow strip between structures may not get enough light or soil ____ 46
Figure 20. Tree shelters installed to protect seedlings at a reforestation site ____ 48
Figure 21. Deer enclosure shows heavy browsing of unprotected understory vegetation in forest on right ____ 49
Figure 22. Posts are placed between trees planted on this Baltimore vacant lot to discourage traffic near trees and prevent illegal dumping on the lot ____ 50
Figure 23. Illegal dumping at a potential planting site ____ 51
Figure 24. Tree-of-heaven and English ivy are common invasive plants in many urban areas of the U.S. ____ 54
Figure 25. Removal of invasive species using a chainsaw ____ 57
Figure 26. Soils at urban planting sites are highly compacted, full of rubble, trash and other pollutants ____ 60
Figure 27. Amending soil with compost at a planting hole ____ 63
Figure 28. Tree planting specification ____ 69
Figure 29. Specification for planting on a steep slope ____ 70
Figure 30. Tree cluster planted on side slope of storm water pond ____ 71
Figure 31. This natural regeneration site has some existing trees that provide a seed source ____ 72
Figure 32. This mulch volcano (left) can be harmful to the tree, compared with a properly mulched tree (right) ____ 74
Figure 33. Signage used to prevent mowing and inform the public of a reforestation project ____ 75
Figure 34. A soaker hose is an efficient way to water newly planted trees ____ 78

LIST OF TEXT BOXES

Box 1. Common Causes of Urban Tree Mortality ____ 1
Box 2. Equipment Needed for the URSA ____ 9
Box 3. Instructions for Planting a Tree ____ 68

Chapter 1: Introduction

The urban landscape can be a harsh environment for trees, complete with a variety of pollutants, temperature extremes, hydrologic modifications, compacted soils, invasive plants, and many other factors that 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 et al., 2002). While the exact causes of urban tree mortality are difficult to pinpoint, and may take years to appear, some common causes are listed in Box 1. Most traditional guidance on planting trees does not adequately address these factors. The purpose of this manual is to provide detailed guidance for anyone planning an urban tree planting project to address these urban impacts and improve the growing environment for the tree.

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 the work of Parts 1 and 2 in this manual series. 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 of this manual 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)					Site Preparation (Chapter 5)		
	Inadequate Soil Volume	Storm Water Runoff	Infrastructure Conflicts	Animal Impacts	Human Impacts	Trash and Debris	Poor Soils	Invasive Species
Highway rights-of-way Page 63	●	◖	●	●	◖	●	●	●
Home lawns Page 68	◖	◖	◖	◖	●		◖	◖
Local roads	●	●	●	◖	●	◖	●	◖
Parking lots	●	●	●	◖	●	◖	●	◖
Parks Page 72	◖	◖	◖	◖	●	●	◖	◖
School grounds Page 76	◖	◖	◖	◖	●	●	◖	◖
Storm water dry ponds Page 80	●	●	◖	◖	◖	◖	●	●
Streams/ shorelines Page 83	◖	◖	◖	◖	◖	●	◖	●
Utility corridors Page 87	◖	◖	●	◖	◖	◖	◖	●
Vacant lots Page 90	◖	◖	◖	◖	●	●	●	●

● = Very likely to be a consideration when planting trees in this location
◖ = May be a consideration, depending on location and site-specific factors
*Page number indicates corresponding page in Part 1 of this manual that provides planting guidelines for specific urban locations

Guidance for conserving and planting trees in specific areas of a development site is provided in Part 2 of this manual. 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		
Photo of 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
Bioretention	• Storm water runoff • Poor soils (e.g., pollutants from storm water runoff) • Infrastructure conflicts (underdrain)	Bioretention and bioinfiltration
Dry swale	• Storm water runoff • Poor soils (e.g., pollutants from storm water runoff) • Human impacts (mowing) • Inadequate soil volume	Alternating side slope plantings Tree check dams
Filter strip	• Storm water runoff • Poor soils (e.g., pollutants from storm water runoff) • Human impacts (mowing)	Forested filter strip Multi-zone filter strip

Table 2. Special Considerations for Planting Trees in Storm Water Treatment Practices		
Photo of Typical Storm Water Treatment Practice	**Special Considerations for Tree Planting**	**Related Storm Water Forestry Practices**
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

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 two cubic feet of usable soil for every one square foot of mature canopy (the area within the projected mature dripline of the tree). Soil volumes of planting areas should be designed to be interconnected 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 tree's rooting area, which also allows for periodic inspection of the planting area. Soils should be amended where needed to improve drainage and fertility.

3. **Provide adequate space for tree to grow.** Design surrounding infrastructure to accommodate long-term growth of 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 and it is not possible to address each possible planting scenario. In these cases, links to additional resources are provided for more information. This manual is organized by the following chapters:

Chapter 2: Urban Reforestation Site Assessment – describes how to evaluate a planting site to determine what to plant based on site conditions

Chapter 3: Basic Planting Design – outlines the basic elements of a planting plan that applies to most planting sites

Chapter 4: Special Considerations for Urban Tree Planting – additional things to consider in a planting plan that are common to urban planting sites

Chapter 5: Site Preparation Techniques – methods to prepare the site for planting

Chapter 6: Planting, Inspection, and Maintenance Techniques – techniques for planting, inspecting, and maintaining trees

Chapter 2: Urban Reforestation Site Assessment

This chapter describes the Urban Reforestation Site Assessment (URSA). This method is used to collect detailed information about planting site conditions to develop an effective planting plan for the site. 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 URSA was designed based on the assumption that planting potential at the candidate site is reasonably good. For more information on methods to select, screen and prioritize candidate planting sites across a watershed or development site, consult Parts 1 and 2 of this manual series.

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

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

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

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

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

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

6. *Hydrology* – evaluates 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* – identifies 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* - evaluates 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 sections will apply to every planting scenario, and each individual section may be adapted for the site. 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 URSA

Site Assessment Resource	Source
Cornell Urban Horticulture Institute's Site Assessment Checklist	Recommended Urban Trees: Site Assessment and Tree Selection for Stress Tolerance (Bassuk et al, 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, et al, 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 (WDFW, 2002)

Some simple desktop preparation is required prior to 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. The goal is to have all the available information about an individual planting area contained in a single form. 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 and equipment 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 two 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 six hours is 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 such as www.benmeadows.com or www.forestry-suppliers.com.

Box 2. Equipment Needed for the URSA

- 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
- Shovel
- pH test kit
- Soil test kits (optional)
- Ping pong balls
- Soil auger

The URSA field form is provided in Appendix A. With the exception of the general site information, all sections of the form 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 URSA are provided below.

2.1 General Site Information

In addition to completing the fields described below, field crews should also take photos of the planting area to record the site and also photograph anything of note as they complete the individual sections of the field form.

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, and/or specific site ID.

Property Owner
Note the name of the property owner. Property owner should be contacted prior to 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.

2.2 Climate

USDA Plant Hardiness Zone
Check the hardiness zone of the site using the USDA Plant Hardiness Zone Map available at: http://www.usna.usda.gov/Hardzone/ushzmap.html. Bassuk et al. (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 (e.g., common under a tree with fine textured leaves) for most of the day. 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.

Micro-Climate Features
Important micro-climate 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 et al., 2003). These areas are typically south-facing, and on sunny days are noticeably warmer than nearby spots. If either of these micro-climate factors exist in the planting area, tree species that are tolerant of drought must be chosen.

2.3 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.

2.4 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 Potential Natural Vegetation Groups, available from the National Forest Service at http://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, 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 (% coverage of the site) of invasive plant species or noxious weeds present adjacent to the planting area. Recording species present at 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: presence of light-seeded species (e.g., maple, sycamore, ash, pine, yellow poplar) upwind of the site (can be fairly far away), or presence of 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.

2.5 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 very 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 results. Sandy soils have a gritty feel and will not form into 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 two 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 inches to 15 inches deep and remove a large handful of soil for examination. Soils with grey mottling and/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 one inch per hour, the site is poorly drained. If drainage ranges from one to six inches per hour, soil drainage is considered moderate. If greater than six 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 two 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.

Another similar test is to dig a hole two 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 and/or soils can be amended before planting.

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 local

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 prior to planting. For example, erosion caused by excessive storm water runoff should be addressed prior to planting 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 local 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.

2.6 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 for each bank individually. 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 local the 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 in the field during a storm event.

Storm water runoff information is used to make decisions about whether and how to modify site drainage to provide storm water treatment using trees or other method, 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, below, or above 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 into 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). A ping pong ball is helpful to determine which way the water flows, when conducting this assessment during dry periods. 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 structure that restrict flood flows onto the floodplain, and the bank height. The stream order will already be recorded during the office preparation, 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 and/or soil mottling and 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 three feet, and second order or higher streams with bank height greater than five 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).

2.7 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 above or below ground 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:

- 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, beaver, neighborhood pets, rodents, or other animals. This may include 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, and/or presence of non-preferred browse species in existing or adjacent forests. Wetland indicators include the presence of wetland vegetation, poorly drained soils with grey mottling and/or foul odor, and 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 prior to 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 prior to 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.

2.8 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 for 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 concentrated flow in Hydrology section), 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 prior to going out into the field. 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.

2.9 Site Sketch

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

- 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, 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.

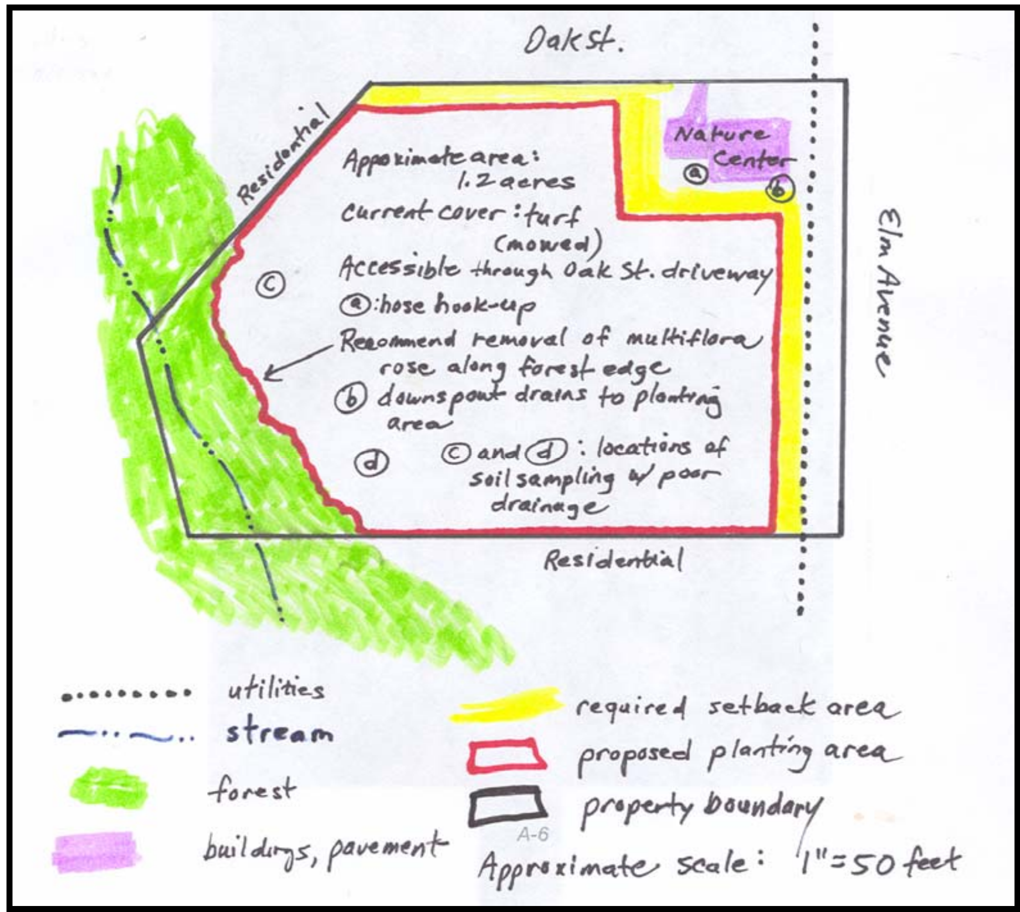


Figure 2. Sample site sketch for an URSA

Chapter 3: Basic Planting Design

Successful urban tree planting involves selection of appropriate species and plant materials, spacing plants appropriately, and developing a realistic planting plan, including a cost estimate. Each decision can be made using data gathered during the URSA. Each is described below.

3.1 Plant Species

The primary purpose of planting design 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 yield the greatest benefit from the tree. Proper species selection will ultimately save money through lowered maintenance and replacement costs and increased landscaping value (Akbari et al., 1992 and ISA, 2000a). Species selection is based on site-specific information evaluated at each planting area, as well as planting objectives. This section summarizes key factors influencing how to select 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, non-native 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 normally 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 provided 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 of 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:

- 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 Influencing Species Selection

Environmental Conditions (from URSA)	Species Selection Guidance	Corresponding Fields in Urban Tree Selection Guide
USDA hardiness zone	Select species tolerant of planting area hardiness zone	Hardness Zone
Sunlight exposure	Select species tolerant of sun exposure at site	Sun Exposure
Micro-climate	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	N/A
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 quality	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/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/Disease Tolerance

The Urban Tree Selection Guide provided in Appendix B can be used to select tree and shrub species that are appropriate for a given site, based on 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 U.S. 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 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 (NCDENR, 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 (NCDENR, 2004). As a caveat, designs 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, mid-story, 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 (NCDENR, 2004; Palone and Todd, 1998).

3.2 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; WDFW, 2002). Some key advantages and disadvantages of the three types of plant materials are compiled in Table 5.

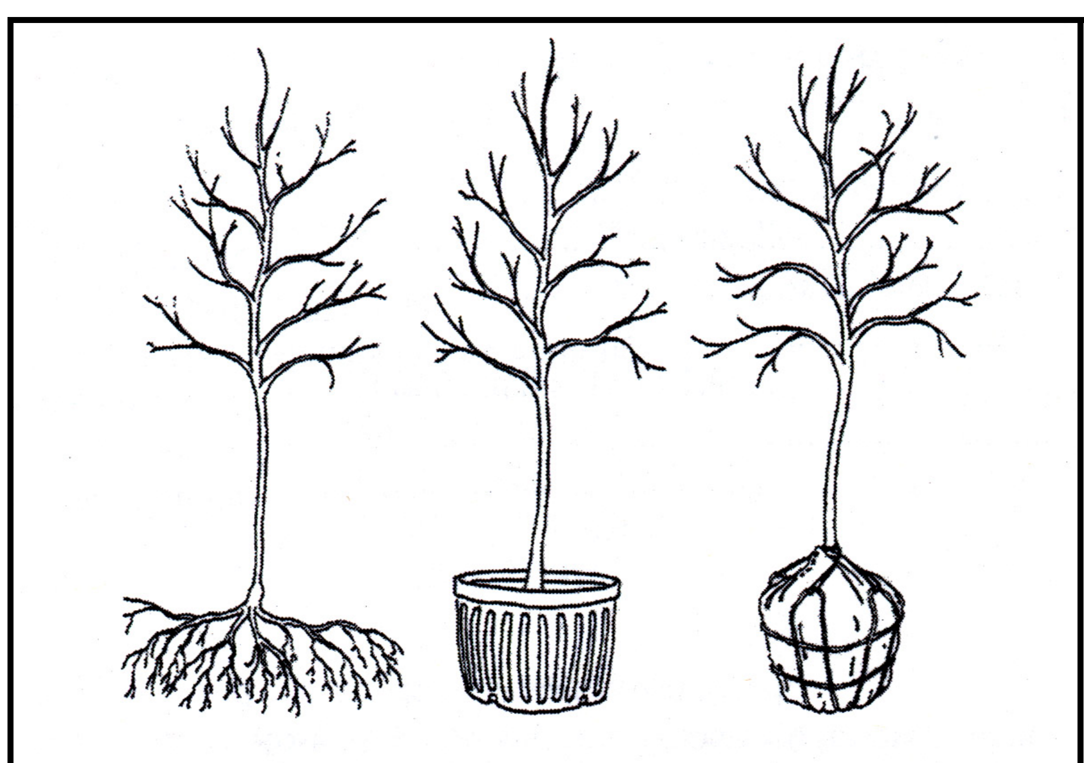


Figure 3. Types of plant materials (from left): bare root, container grown, and balled and burlapped (Illustration by Nina DiRenzo, used with permission from Nina Bassuk, Director of Cornell Urban Horticulture Institute)

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), Tree Trust (2001), Hairston-Strang (2005), Palone and Todd (1998), and WDFW (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 root. 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 the 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 four to five 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 four-inch caliper. Larger trees and shrubs are sold by the caliper inch, which is defined as the diameter of the stem measured six inches above the ground (or twelve inches above the ground for trees greater than four inch diameter). Trees larger than two-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 approach and successful size plant material is bare root seedlings (Buckstrup and Bassuk, 2000; NCDENR, 2004), provided special techniques are used to prevent root desiccation (Chapter 6). 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, and 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 et al., 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 will require less pruning after planting, become established more quickly, and are more resistant to damage from winds and other stressors (Mock, 2003). 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).

3.3 Plant Spacing and 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.

When planting in larger spaces, 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; WDFW, 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 day.

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 (> 400 trees per acre) helps to achieve forest canopy closure more quickly, which is turn reduces competition from weeds (Hairston-Strang, 2005). However, higher densities (> 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	¾" DBH tree	14	160
3	2.5" DBH tree	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-feet-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-feet-by-14-feet achieves the desired stem density. The plant material in this scenario is at least several feet high and around ¾" 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-foot-by-17-foot spacing used results in a canopy tree density that is comparable to what is typically found in a mature forest.

Source: ACB (2000)

For large planting projects that involve using 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):

$$\textit{Number of plants needed} = \frac{\textit{length (ft) x width (ft) of planting area}}{\textit{50 (sq ft)}}$$

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.

Palone and Todd (1998) note that there are two schools of thought regarding plant layout and spacing when re-creating a forest: uniform plant distribution versus random plant distribution. 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.” However, over time, tree mortality will compensate for uniformity and leave vacant spaces between trees, as well as opportunities for germination of natural seed dispersed 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 a forested situation (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.

3.4 Planting Plan

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 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)

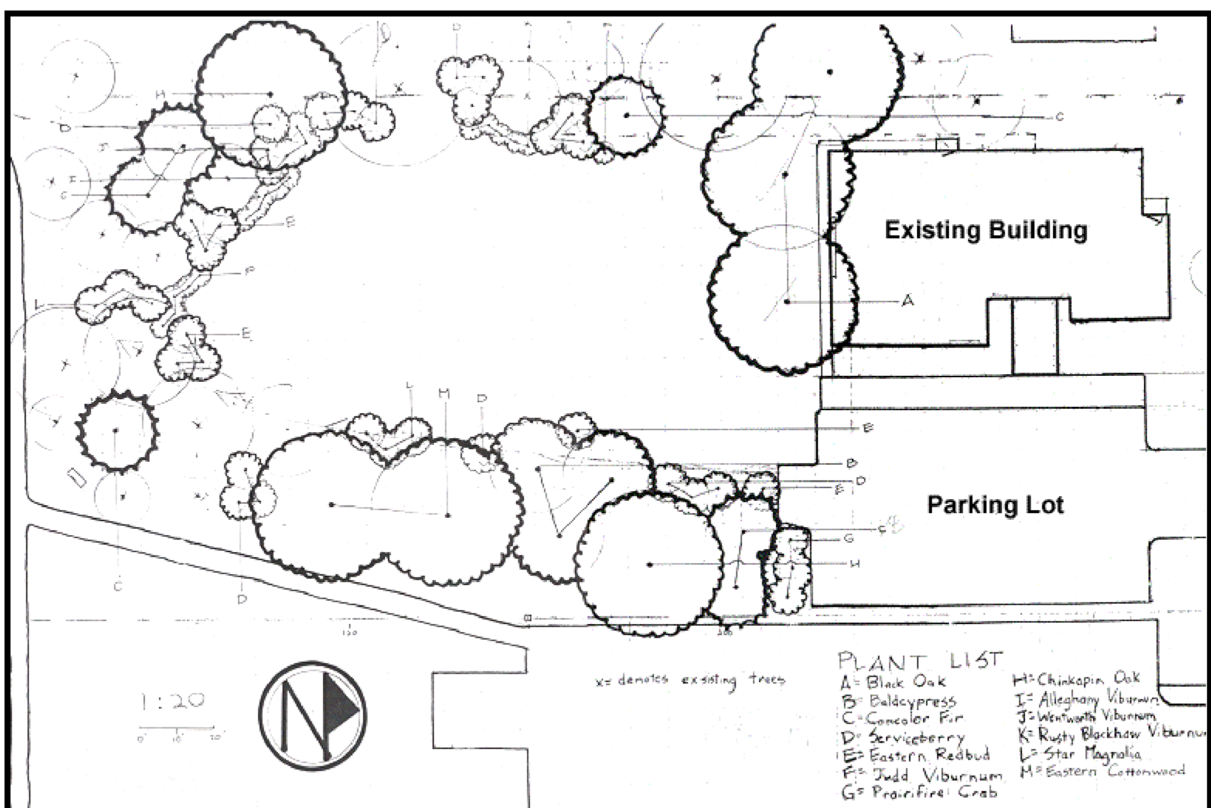


Figure 4. Example planting plan for an urban reforestation site (Source: Omaha Public Power District)

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 range 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 assure 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 each
	Balled and burlapped trees	\$35.00 - \$400.00 each
Supplies	Tree Shelters (12”-72”)	\$1.00 - \$4.00 each
	Tree Stakes	\$1.00 – 2.00 each
	Mulch	\$6.00 to \$20.00 per cubic yard
	Compost	\$11.00 to \$20.00 per cubic yard
Source: Palone and Todd (1998), Environmental Concern, Inc. (2005), Octoraro Native Plant Nursery (2004), Tree Trust (2001), Hairston-Strang (2005), and Chollak and Rosenfeld (1998)		

It is important to note that units costs for plant materials 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 bushhog 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, mulch, weed control, watering, or supplemental plantings. Appendix C provides a worksheet for estimating total project costs for reforestation.

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 growing factors, and imposes unique stressors on trees. Conflicts between trees and infrastructure (e.g., utilities and pavement) may both 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, effective storm water treatment, reduced infrastructure conflicts, and tree protection from other impacts.

4.1 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 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 useable 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, according to VCE (2002).

Figure 5. Typical urban tree pits only provide 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

dripline of the tree and provide two cubic feet of useable soil per square foot (Grabosky et al., 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).

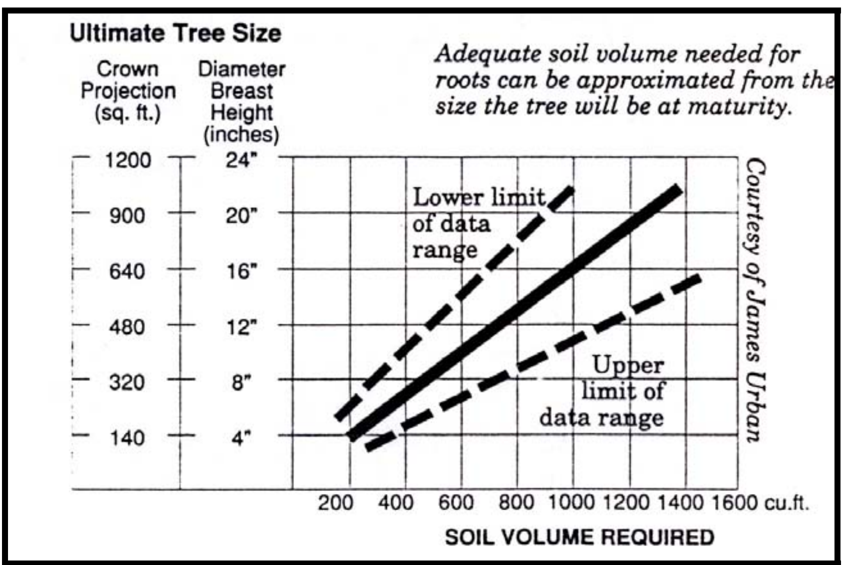


Figure 6. Soil volume required for various size trees (Source: James Urban)

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 is:

$$\textbf{Soil Volume} = [((3.14 \times r^2) \times LAI \times ER \times 0.2) / AWHC] \times RF$$

where:

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

LAI = Leaf Area Index; the ratio of total tree leaf surface area to crown projection. 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. Data can be derived from Pan Evaporation data.

AWHC = Available Water Holding Capacity; varies by soil type, but typically ranges from 10 to 20%. Data 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 begin defined as a period with less than the rainfall amount that constitutes a critical rainfall event. Data is 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 useable soil is provided in the planting area to a depth of three feet. The calculation and the earlier rule of thumb are based on the assumption that the soil volume provided is useable, 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 three 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 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 re-designed, the number and/or size of trees planted at the site should be reduced to ensure that individual trees have a decent chance of survival.

4.2 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 occurs when rainfall that would normally soak into the ground can only infiltrate into a small area around each planting pit. The rest becomes storm water runoff that is efficiently directed into nearby storm sewers, making it unavailable for tree growth (Figure 7). Designing urban planting sites to work with the expected volume of storm water and rainfall helps ensure an appropriate water balance for trees and can provide water quality benefits by using trees to remove pollutants from storm water runoff. Part 1 of this manual summarizes the water quality benefits of trees.

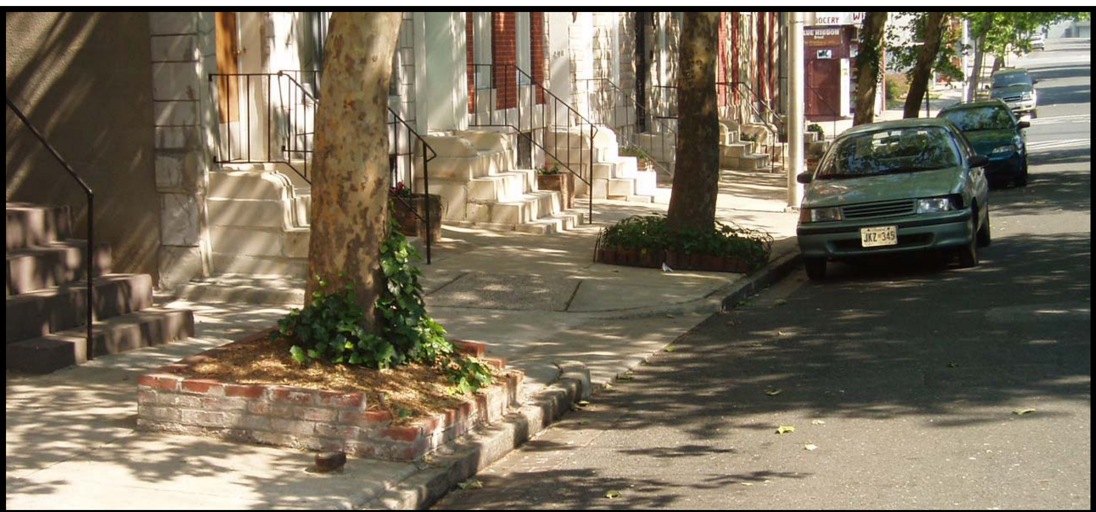


Figure 7. Urban trees in raised planters receive very little water from rainfall or runoff

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, and is used to identify appropriate storm water 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 at Potential Planting Sites

Condition	Description	Storm Water Strategy	Planting Strategy
Under-Capacity	No runoff is received; runoff bypasses site in pipes or ditches, or is infiltrated before reaching the site	Daylighting or split the flow	Choose drought-tolerant species or provide irrigation
At-Capacity	Receives only sheet flow; runoff travels over 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	Perimeter treatment practice or pipe the flow	Plant wet-tolerant species using large stock

Under-Capacity Sites

Under-capacity sites do not currently receive concentrated storm water runoff or sheet flow and consequently do not provide any 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. Under this condition, the site does not provide any treatment of storm water runoff and may require supplemental water in order to grow.

Figure 8. This under-capacity site does not receive any storm water runoff

Identifying under-capacity sites
Several factors evaluated during the URSA help determine if a planting area is under-capacity. 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. 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 into 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, if pervious), the site is normally 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 currently 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 the 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). A small soil berm may also be created around planting hole to hold water near the tree.

At-Capacity Sites
An at-capacity site currently receives sheet flow only from adjacent land, but the amount does not overwhelm the treatment capacity of the site (Figure 9).

Identifying at-capacity sites
Planting sites that are at-capacity will not have any evidence of shallow concentrated flow or upslope drainage area outfalling to the site. Sheetflow may be observed. However, sheet flow is difficult to maintain over long distances, so under this condition, runoff from adjacent land travels over impervious surfaces less than 75 feet (or pervious surfaces less than 150 feet). Slope of the contributing length should be taken into account by subtracting 10 feet for each foot of slope over three to arrive at the corrected contributing flow length.

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

Storm water strategies
Areas that are at-capacity are prime candidates 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 it does not conflict with the intended use of the site, trees planted can be part of a treatment design. The forested filter strip incorporates a small depression and berm to temporarily pond water and allow it to enter the forested area slowly with no erosion. Figures 10 and 11 illustrate the forested filter strip and Part 2 of this manual provides guidance on its design.

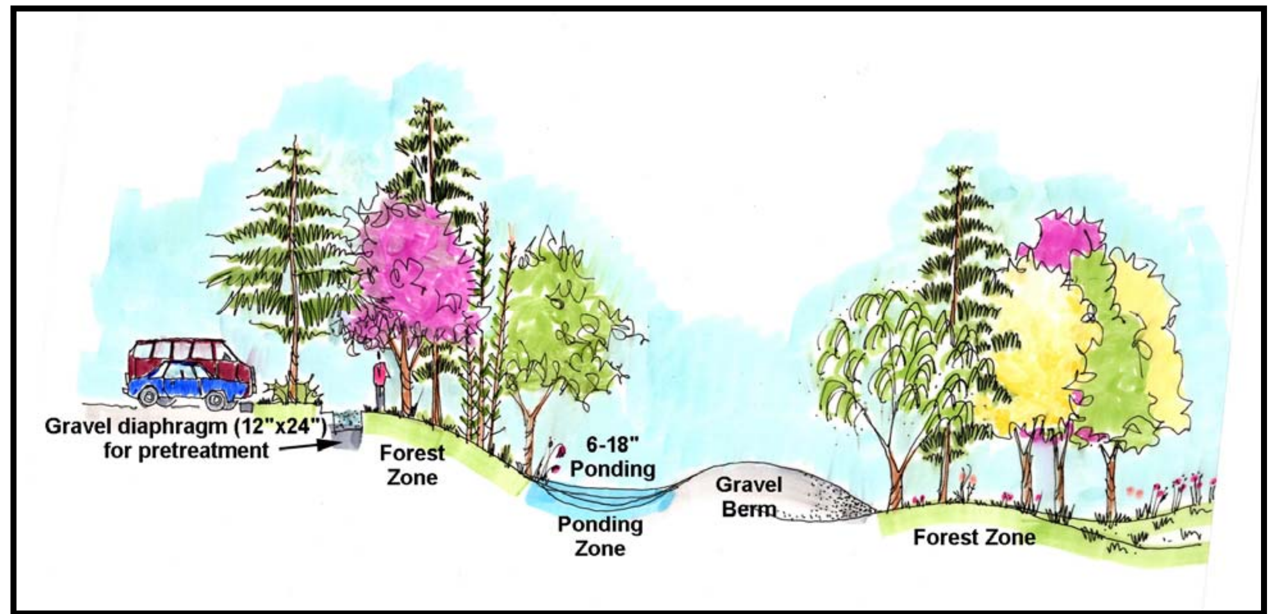


Figure 10. Forested filter strip profile (Graphic by Matt Arnn)

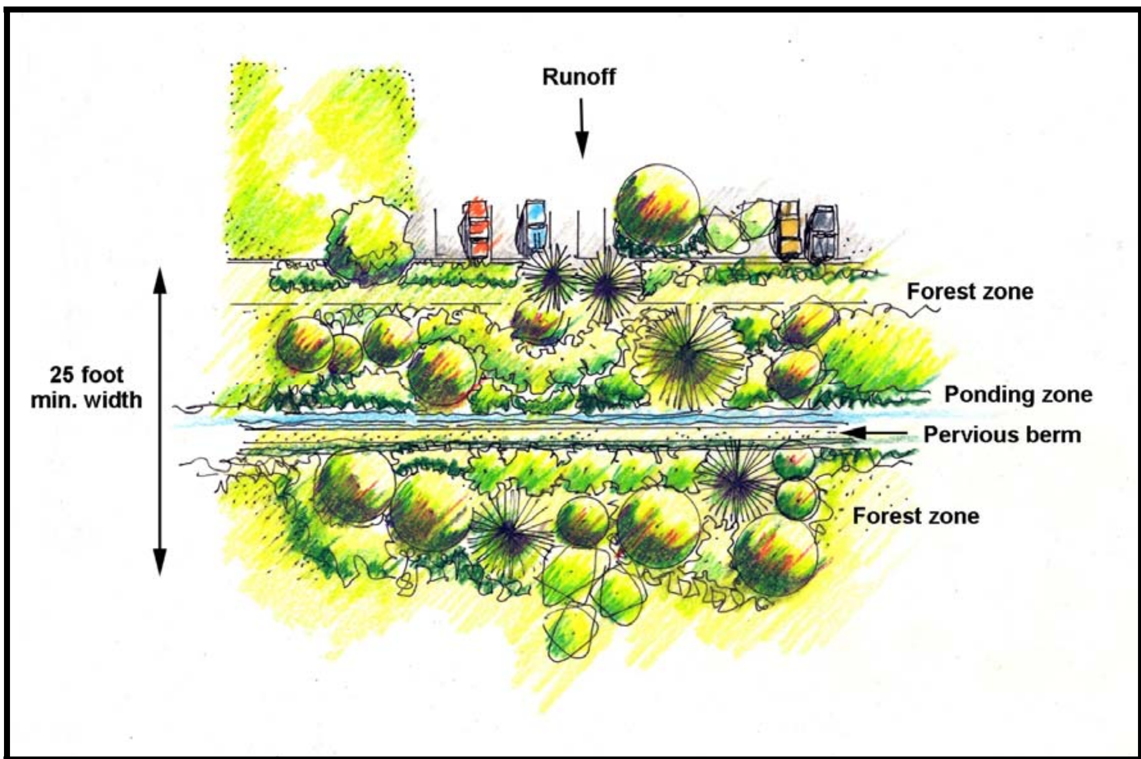


Figure 11. Forested filter strip plan view (Graphic by Matt Arnn)

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). 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
Sites that receive shallow concentrated flow are over-capacity. These sites may also receive runoff from an upslope drainage area (Figure 12). Over-capacity sites typically have some potential for treating storm water runoff at the perimeter. Under this condition, runoff from adjacent land travels over impervious surfaces greater than 75 feet or pervious surfaces greater 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 have evidence of shallow concentrated flow. Common indicators include, rills, gullies, erosion, and/or 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 prior to 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 four to five feet per second for a two-year design storm (Claytor and Schueler, 1996). Figure 13 illustrates a bioretention facility that incorporates trees into the design. Part 2 of this manual and Claytor and Schueler (1996) provide design guidance for bioretention facilities.

At sites with runoff velocity greater than one foot per second, concentrated flow may already have begun to create an eroded 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 prior to planting trees. See Schueler and Brown (2004) for more information on using bioengineering techniques.

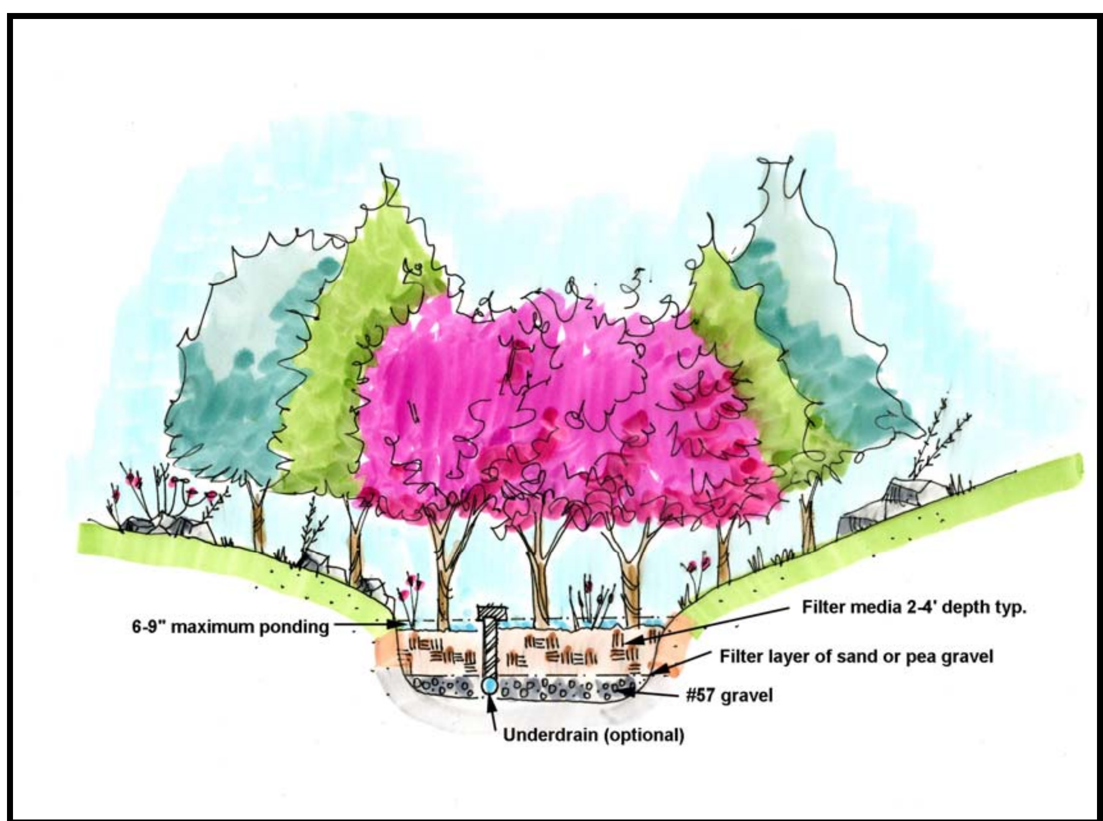


Figure 13. Bioretention facility with trees (Graphic by Matt Arnn)

Planting strategies
Since trees in over-capacity sites may be subject to high flows and erosion, larger stock should be planted that is tolerant of occasional inundation (see Appendix B). 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 managed to divert excess flows.

4.3 Reducing Conflicts Between Trees and Infrastructure

The built nature of the urban landscape presents a unique challenge to locate planting areas that will not cause damage to adjacent infrastructure, such as pavement, structures, and utilities (Figure 14). Research has shown that the municipal costs to repair infrastructure damaged by trees can be high. The annual cost in California alone to repair sidewalk and road damage by trees is estimated at more than $42 million (Dodge and Geiger, 2001). Where trees and infrastructure conflict, the offending trees are often removed, or pruned to the point where they no longer resemble trees or provide their intended benefits. To reduce this conflict, but still incorporate as many trees as possible into the urban landscape, designers must make changes in:

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

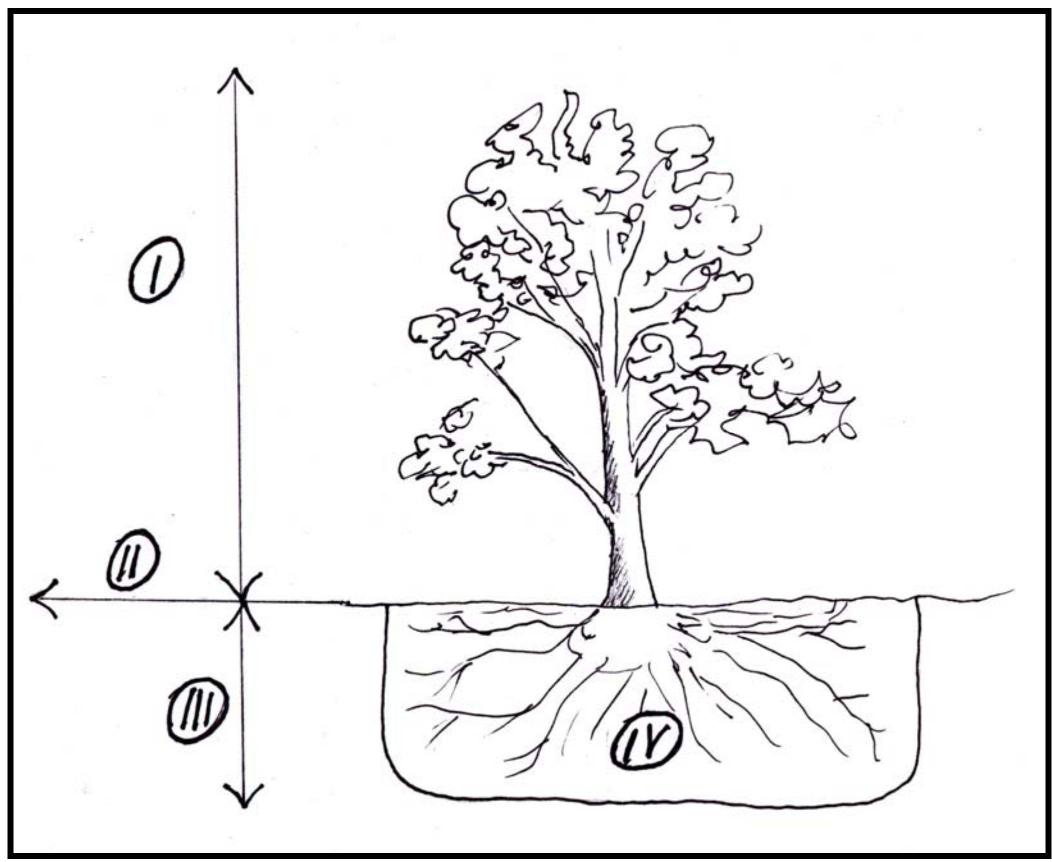


Figure 14. Trees may conflict with infrastructure (I) above-ground, (II) at the surface, (III) below-ground, or (IV) in the rootzone

These types of changes can prevent tree/infrastructure conflicts in new developments, or can remedy existing conflicts when used in a retrofit situation. Making such changes to the way sites are built can reduce damage to both infrastructure and trees, and allow integration of trees into the urban landscape to provide maximum benefits. Part 2 of this manual 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. Each strategy is discussed below.

Table 9. Methods to Reduce Conflicts Between Trees and Infrastructure

Type of Infrastructure	Methods to Reduce Tree/Infrastructure Conflicts			
	Species Selection	Site Design & Layout	Construction Materials	Maintenance Strategies
Utilities	X	X	X	X
Pavement	X	X	X	X
Structures	X	X	X	X
Lighting & 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 are planted underneath these lines, they can cause 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.

The best way to avoid conflicts between trees and overhead wires is to install utilities underground. Many communities are doing this already, 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 situation where utility wires needed to be upgraded anyway. If utilities cannot be placed underground, they can be located on one side of the street only. 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, as opposed to species with a pyramidal growth form, such as Bradford pear (Figure 15).

Table 10. Recommended Minimum Setbacks for Overhead Wires		
Recommended Setback	**Description**	**Source**
10-15 feet*	Setback between height of mature tree and height of overhead wires when planting under utility	Gilman, 1997; Head et al, 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 et al. 2001
20 to 40 feet	Distance setback for large trees (> 50 ft.)	Nebraska Forest Service, 2004; Head et al. 2001
20 feet	Distance setback from transmission right-of-way for all trees > 15 feet	Kochanoff, 2002
*Based on the typical overhead wire height, trees planted under utilities should be 15-30 feet to maintain this height setback (PSU, 1997; City of Seattle, no date; Kochanoff, 2002; City of Chicago, no date)		

Figure 15. Bradford pears pruned extensively 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 minimum 10-foot setback is recommended (Head et al., 2001; Gilman, 1997; GFC, 2002).

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. Roots may cause structural failure of sewer pipes as well, although structural failure is most often due to inadequate construction (Randrup et al., 2001). This interference between trees and sewer systems is most likely to occur with older or deteriorating systems (Randrup et al., 2001). Use of appropriate construction materials and methods can prevent this deterioration, but little can be done for existing failing systems short of costly upgrades. A more cost-efficient approach used by homeowners is to periodically flush out the pipes using a roto-rooter 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. A 15-25 foot setback between trees and perforated pipes is suggested by Shaw and Schmidt (2003), MDE (2000) to reduce this conflict.

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 in between sidewalks and streets (called tree lawns). Once tree roots cause damage, methods to reduce or correct the damage can either harm the tree, or the tree may be removed completely in order to correct the problem. 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. Wong et al. (1988) found that asphalt sidewalks had significantly more conflicts with roots than concrete sidewalks. City of Saint Louis (2002) and Day (1991) found that potential for sidewalk damage is increased where planting soils are compacted, because roots will tend to grow towards the surface in search of water and oxygen.

Figure 16. Tree roots cause adjacent pavement to crack

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/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.

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 only feasible for new developments, but could be applied as a retrofit where sidewalk renovation is planned in conjunction with relocation or repair of underground utilities. Table 11 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.

Table 11. Alternative Sidewalk Design Methods	
• Larger planting space	• Tree islands
• Curving sidewalk	• Narrower streets
• Pop-outs	• Bridging
• Nonstandard slab sizes	• Lower planting sites
• Monolithic sidewalks	• Modified gravel layer
• Increased right-of-way	• Sidewalk elimination
Source: Costello and Jones (2003)	

Figure 17. 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 et al, 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 ten feet (Randrup et al., 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 (Table 12). 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 sidewalk while preventing sidewalk damage. Costello and Jones (2003) provide additional information on alternative sidewalk materials.

Table 12. Alternative Construction Materials to Reduce Tree/Sidewalk Conflicts	
Alternative Sidewalk Materials	
• Reinforced slab	• Permeable pavers
• Thicker slab	• Recycled rubber
• Expansion joints	• Mulch
• Pervious concrete	• Grind edge
• Asphalt	• Ramps or wedges
• Decomposed granite and compacted gravel	• Mudjacking
Materials Used in Root Zone	
• Root barriers	• Root channels
• Continuous trenches	• Foam underlay
• Root paths	• Steel plates
• Structural soil	
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 range from use of 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, and several studies have noted that they are most effective in situations where tree/infrastructure conflicts are not a major concern, for example, sites with uncompacted soils or sufficient planting area (Gilman, 1997; Harris et al., 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 situation. 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 et al. (1999), and Watson and Neely (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 in a linear street tree design.

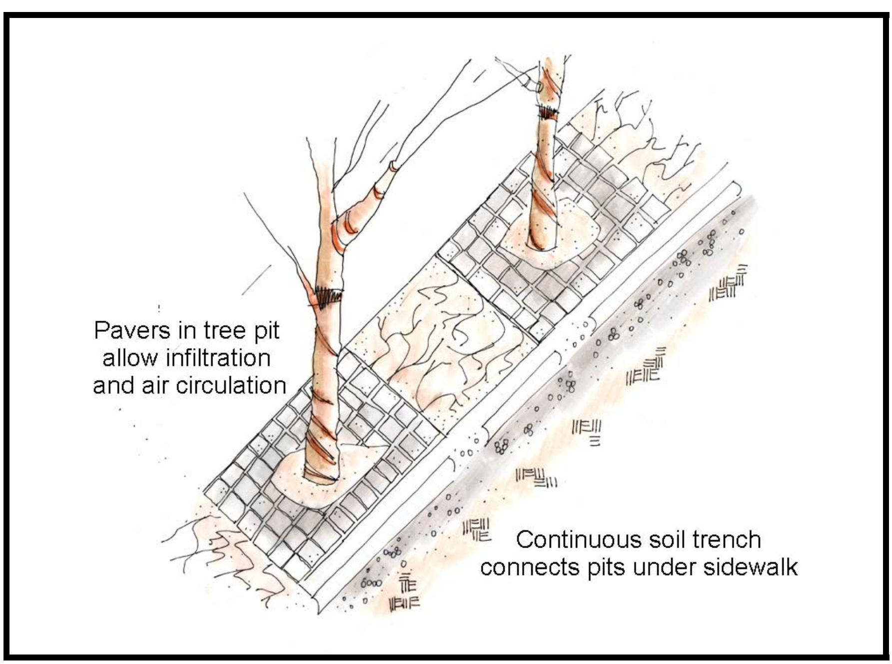


Figure 18. Structural soils used in a street tree application (Graphic by Matt Arnn)

Structures

Trees planted next to structures may not have enough room for proper root development and are subject to increased heat load reflected off the 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 and 20-25 feet for large trees (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 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 2/3 the height of the tree as crown.

Figure 19. Trees planted in 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 a distance setback of 10 feet between trees and lighting, and increasing this distance for very large trees. 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 (e.g., prune existing trees so limbs do not extend below eight feet from the ground).

4.4 Protecting Trees from Human and Animal 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 beaver can impact newly planted trees through browsing or gnawing on trees. 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 beaver, deer, and human impacts are described below. In addition, installing signs, fencing, and/or flagging can be a useful tool at any planting site to let the public know about the reforestation project, and to protect the trees from impacts.

Beaver

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:

- Deer repellent, which has an unpleasant odor and will drive the beaver 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 three-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 Kwon (1996), Jensen, et al. (1999), LeBlanc (1997) and http://dep.state.ct.us/burnatr/wildlife/factshts/beaver.htm.

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 five 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 are generally not preferred by deer are provided at:

- Maryland Department of Natural Resources. Less palatable Landscape Plants. http://www.dnr.state.md.us/wildlife/ddmtplants.asp

- Rutgers Cooperative Research and Extension. Landscape Plants Rated by Deer Resistance. http://www.rce.rutgers.edu/deerresistance/default.asp

- University of Minnesota Extension Service. Coping with Deer in Home Landscapes http://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.

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

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

Deer repellent is a malodorous substance that drives deer away, and commercially available products include in-soil systemic tablets and foliar sprays. System repellent tablets are most effective at moderate deer densities while foliar sprays work best for short term (8-12 weeks) protection from browse (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 www.agnr.umd.edu/MCE/Publications/PDFs/FS810-A.pdf 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 for repair. A more cost-effective option is to plant new trees in clusters and fence them in (Hairston-Strang, 2005).

Figure 21. Deer enclosure shows heavy browsing of unprotected understory vegetation in forest on right (Photo courtesy of Will McWilliams, USFS NE Area/FIA)

Human Impacts

In urban areas, human impacts can cause damage to newly planted trees from automobiles, vandals, pedestrian traffic, and mowing. Accidental damage from mowing is most common in tree plantings in formerly turf areas. Studies have found that the most common injury to curbside trees is from vehicles (Foster, 1978). Damage to trees from vehicles or mowers can open wounds for entry of disease. 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 are placed between trees planted on this Baltimore vacant lot to discourage traffic near trees and 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 often need to be prepared for planting by removing trash and other debris, controlling invasive plants and amending soil. The URSA worksheet indicates what level of site preparation is needed for successful reforestation at each planting site. Methods for preparing urban sites for planting are described in detail below.

5.1 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 (Figure 23). If present, trash and debris should be removed from the site prior to 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. Illegal dumping at a potential planting site

Evaluating the Site

Several types of information are collected during the URSA to determine cleanup needs prior to planting, as shown in Table 13.

Table 13. 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 # of pickup truck loads will determine how many staff/volunteers are needed, and 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 using volunteers from the community that are led by a local watershed group and/or 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 websites, 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 hazmat 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: 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 (plastic, glass, aluminum, yard waste, etc.) and non-recyclable 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 follow-up 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 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, etc.). 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.

5.2 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 non-native plants can be invasive, the majority of invasive plants are non-native 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 share many of the following characteristics (Haber, 1997):

- Rapid growth
- Grow under a wide range of climate and soil conditions
- Produce abundant seeds
- Have adaptations that promote easy dispersal

- Seeds stay viable for many years in soil
- Have adaptations such as bad taste or odor that reduces herbivory by larger animals
- Lack insect pests or pathogens in new ecosystem to keep them under control

Evaluating the Site

Invasive plants that will limit the survival of newly planted trees should be removed prior to 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 et al. (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 U.S. include: oriental bittersweet, purple loosestrife, Japanese knotweed, porcelainberry, Canada thistle, multiflora rose, kudzu, mile-a-minute, 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 et al. (2004) for the northeast U.S., Miller (2003) for the southern U.S., and the resources listed below:

- USDA PLANTS Database: http://plants.usda.gov/
- Invasivespecies.gov: www.invasivespecies.gov

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

Table 14 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 14. Invasive Plant Indexing System	
% Invasive Plant Coverage/Acre	**Ranking**
0 – 10	None – Very Light
10 – 25	Light
25 – 50	Moderate
> 50	High
Source: Galli et al. (2003)	

Galli et al. (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; Invasivespecies.gov, 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 non-native 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 five years to successfully eradicate invasive species from a site (May, 2001).

Selecting and Implementing Invasive Plant Control Methods

Methods to control invasive plants fall into four major categories: physical, chemical, cultural and biological controls. Physical methods include hand 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 vs. annual, method of propagation), level of infestation, site characteristics, and budget and time constraints (May 2001; Haber, 1997; PERT, no date). Table 15 provides a comparison of each method, followed by additional detail on implementation. The most applicable methods for urban areas are hand removal, mechanical removal, chemical control, and cultural methods.

Table 15. Comparison of Invasive Plant Control Methods				
Method		**Advantages**	**Disadvantages**	**Applicability**
Physical	Hand Removal	• Inexpensive • Has little ecological impact	• Labor intensive	• Works for annuals or taprooted plants • Best used on small areas
	Mechanical Removal - 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
	Heavy Equipment Removal	• 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 two 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 one 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

Hand removal
Hand removal 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 removal
Mechanical 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, et al, 2001). The mower blade should be set high enough to cut the weeds but not the desired vegetation (May, 2001) and cut fragments should be collected if species are capable of re-sprouting from stem or root fragments (Tu et al., 2001).

Figure 25. Removal of invasive species using a chainsaw

Heavy equipment removal
Heavy equipment removal 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 et al., 2001). Solarization is used for weeds whose seeds are sensitive to temperature changes. This method may cause significant bio/physical/chemical soil changes lasting up to two years that will not allow for new plant growth (Tu et al., 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 et al., 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 respond to girdling by re-sprouting (Tu et al., 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 flower seed or set, or at the young seedling/sapling stage (Tu, et al., 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 et al., 2001). Herbicides should only be used if mechanical, cultural and biological means are not acceptable or feasible and should only be applied during the growing season by a trained, certified pesticide applicator and 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 limits growth or reproduction. This method is best used on large, established populations, but does not completely eradicate invasive species. Biological controls typically take about three to eight years to see 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 U.S. can be found in Van Driesche et al. (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), 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. 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 become established. Additional guidance on IVM and implementation of specific invasive plant control methods is provided in Tu et al. (2001) and MDSHA (no date).

Costs of Invasive Plant Control

The costs to control invasive plants can range widely, due to the variety of methods available for control. Examples of costs for commonly used methods include $12 per acre for mowing, and $54 per acre for herbicide application (USDA, no date). Costs for specific invasive plant removal projects in North Carolina, New York and Rhode Island ranged from $50 to $1000 per acre (PFWP, 2001a; PFWP, 2001b; NCWRP, no date).

5.3 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 (VCE, 2002; Coder, 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 et al., 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 highly compacted, full of rubble, trash and other pollutants

Due to the unique properties of urban soils, most need to be amended prior to 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 sulphur. These amendments are described below.

- *Compost* **–** Compost is decomposed organic material that 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 soil structure in clay soils (Chollak and Rosenfeld, 1998).

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

- *Sulphur* – Sulphur comes in two forms: agricultural sulphur or aluminum sulphate 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 the samples have readings that exceed 300 psi in the top 15 inches of soil (Duiker, 2002). When soil bulk density is analyzed, bulk density greater than 1.5 g/cm^3 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 16 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 16. 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/m3)	<1.4	>1.5	Add compost or peat
Bulk density of loam (mg/m3)	>1.5	>1.7	Add compost or peat
Aeration porosity (% 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 top soil
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 (meg/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	1000	Add gypsum or sulphur, 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, 2002).

Application rates for lime, gypsum and sulphur vary and should be determined by soil test results for pH and macronutrients such as nitrogen, sulphur, potassium, magnesium, and calcium. Unterschuertz (1997) and Muntean (1997) promote adding 50 to 100 pounds of gypsum per 1,000 square feet to improve the structure of heavy clay soils at the same time as compost incorporation. 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). Sulphur is required as elemental sulphur and requirements range from two to five pounds per 1000 square feet annually (Stahnke, 2004; Muntean, 1997).

Soil should be amended at individual planting holes to a depth of two to three feet (Figure 27). Soils deeper than three 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).

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.

Figure 27. Amending soil with compost at a planting hole

The planting plan for the reforestation project should include a site sketch indicating the boundaries of the areas to be amended and/or location of planting holes, and 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 prior to implementation. A sodcutter, bushhog 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 non-woody and non-invasive. Incorporating the vegetation into the soil will require approximately eight weeks prior to replanting the site because of the time required to decompose the incorporated material (Chollak and Rosenfeld, 1998). Equipment needed for soil amendments are listed in Table 17.

Table 17. Equipment for Urban Soil Amendment Projects

Equipment	Use
Sodcutter or bushhog	For vegetation removal
Various soil amendments	Added to soil to improve quality
Measuring tape	To measure planting area for quantifying amendment application rates
Wheelbarrow	For removal of rocks, rubble, vegetation, excess soil
Gloves	For handling soil amendments
Pickup truck	For disposal of trash, vegetation and excess soil from site, and delivery of amendments
Tarp	For storing soil from planting hole
Large bucket	For mixing soil amendments
Shovel, spade or auger	For 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 six-inch diameter root ball, assuming soils are amended to a depth of 2.5 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 new planted trees. Each of the planting and maintenance elements essential to ensure a healthy future for new trees and shrubs are described below.

6.1 Obtaining and Storing Plant Materials

This section describes methods for obtaining and storing plant materials prior to 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 non-profits. Table 18 provides a description of each source. Web resources for obtaining plant materials are provided below:

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

- National Arbor Day Foundation Tree Store
  http://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
  http://www.nanps.org/sources/frame.shtml

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

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

Table 18. Sources of Plant Materials	
Plant Material Source	**Description**
Private nurseries	Wide range of local private nurseries, some 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 NRCS 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.
Non-profits	Trees can be ordered from national non-profits such as American Forests and National Arbor Day Foundation, or from a wide range of local non-profits. 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 references of people who have used the nursery before. Place orders early to ensure the best selection (e.g., prior to early spring), and consider ordering ten to 15 percent more trees than is 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, they should be protected by 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 *prior* to 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 prior

to planting. If possible, bare roots should be dipped in hydrogel[1] or muddy water, then stored immediately in large plastic bags until planting. If hydrogel is not used, the tree roots should be soaked in water for 12-24 hrs before planting (Buckstrup and Bassuk, 2003).

6.2 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 19. 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) prior to 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 19. 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 (auger, etc.)	Spring/fall, summer if irrigated
Balled and burlapped	Use backhoe (or other specialized equipment) or hand plant.	Spring/fall

Source: Palone and Todd (1998), WDFW (2002), NJDEP (2000)
*One Cornell University study has shown that fall-planted bare-root trees grow better than spring-planted bare-root trees during the first growing season (Trowbridge and Bassuk, 2004).

One of the most important planting guidelines is too make sure the tree is not planted too deep. 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, two to three inches above the base of the trunk flare, than to plant it at or below the original growing level (ISA, 2003b).

[1] 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).

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 3, including variations for specific plant materials. Specifications for planting a tree are illustrated in Figure 28.

Box 3. Instructions for Planting a Tree

1. Dig a hole that is two to three times as wide as the root spread, container diameter, or B&B root ball. The hole should be no deeper than the root ball height, or depth of soil in 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 B&B 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 one year. Stakes should be extended into undisturbed soil.

9. Apply a two to four inch layer of mulch over the entire rooting area, leaving a three-inch circle of bare soil around the trunk.

10. Water the tree thoroughly.

Sources: Buckstrup and Bassuk (2003), WDFW (2002) Greenfeld et al. (1991), DOD (1996), Palone and Todd (1998), Trowbridge and Bassuk (2004) NVRC (1997), Haefner et al. (2002), Flott (2004)

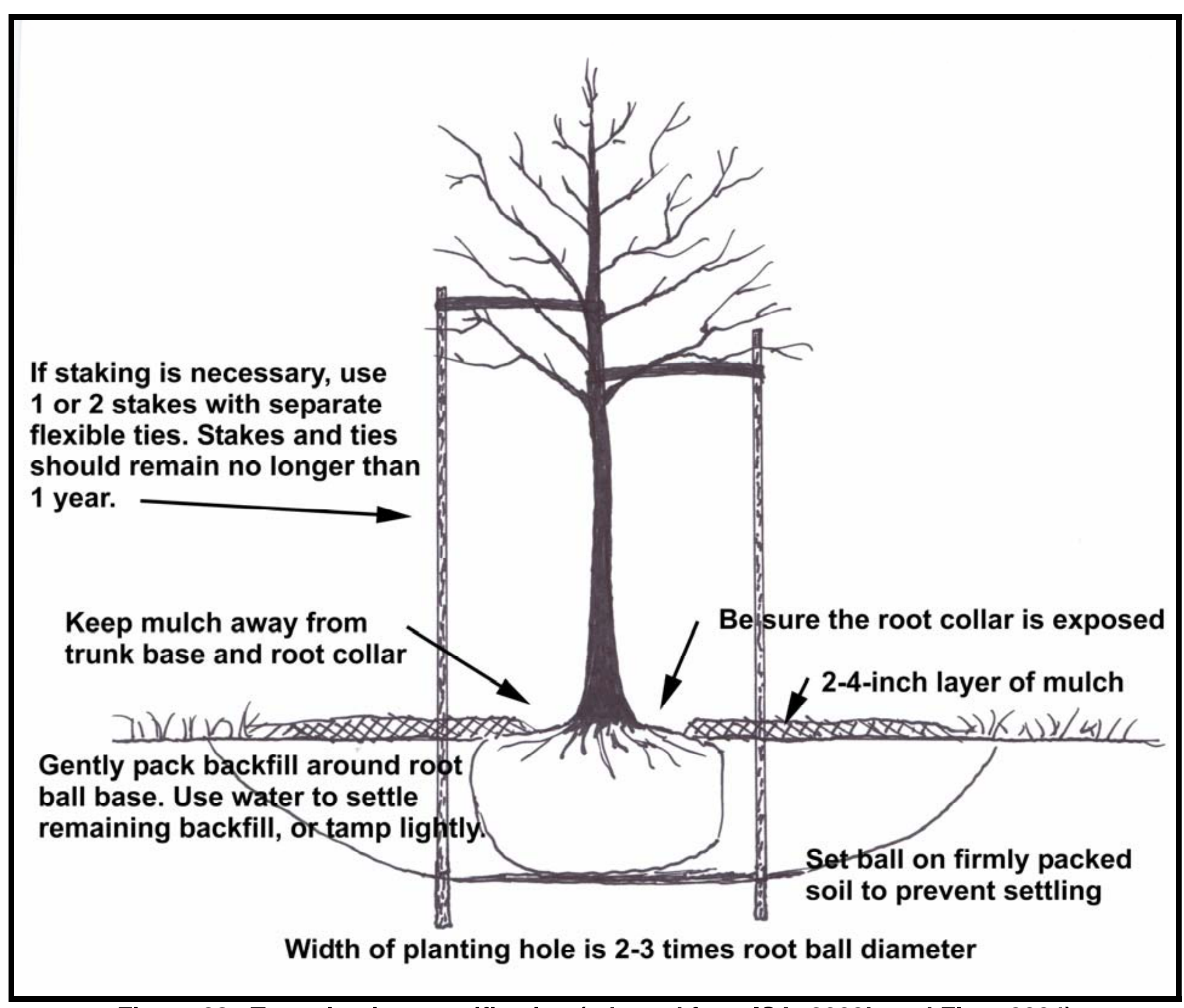


Figure 28. Tree planting specification (adapted from ISA, 2003b and Flott, 2004)

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 two-fold approach: control the storm water and stabilize 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 et al., 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 et al., 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, et al, 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 (one 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.

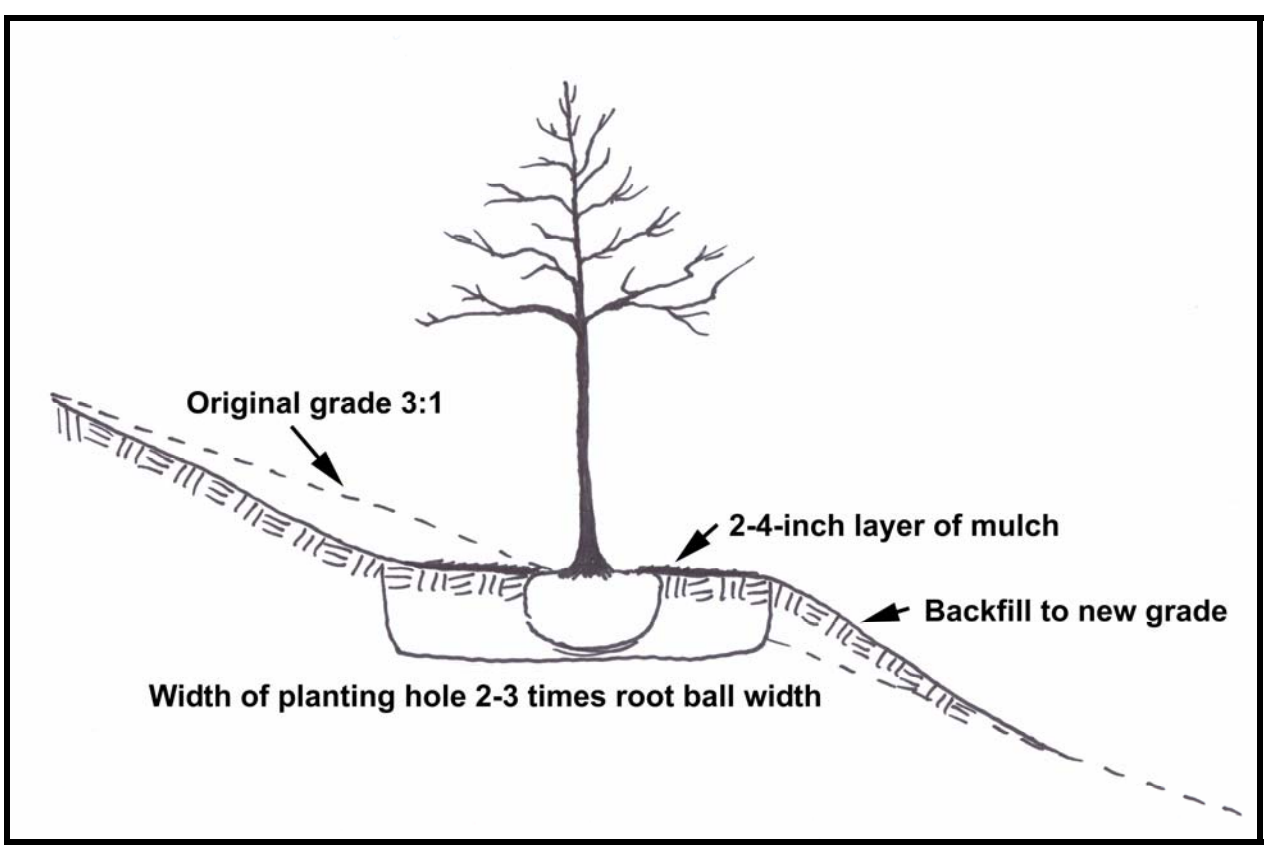


Figure 29. Specification for planting on a steep slope

Figure 30. Tree cluster planted on side slope of a storm water pond (Graphic by Matt Arnn)

Encouraging Natural Regeneration

Natural regeneration is the process by which trees and forests are established from seeds produced and germinated on site. Most of the eastern U.S. gets enough rain that trees will eventually regenerate in sites where they are not kept out by mowing, cultivation, browse, 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 disadvantages of this technique in urban areas is the high potential for regeneration of invasive or non-native species with cessation of mowing. Table 20 summarizes the advantages and disadvantages of natural regeneration.

Table 20. Advantages and Disadvantages of Natural Regeneration

Advantages of Natural Regeneration	Disadvantages of Natural Regeneration
• 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 and/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: Willistin et al. (1998), Featherstone (2000)	

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 desirable tree seed sources nearby (Figure 31) and adequate seed dispersal methods, bare mineral soils with good seed to soil contact, low compaction, controlled deer populations, limited invasive species, and current vegetative cover that does not consist of thick sod-forming grasses such as fescue (Hairston-Strang, 2005). 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 are present, the potential for seed dispersal is greater.

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. This includes improving soil conditions, controlling invasive plants, installing fencing or other methods to control deer, discing (mixing) and/or herbicide application 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 et al., 1998).

Maintenance of natural regeneration sites is similar to that of 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.

6.3 Post-Planting Tree Protection

Mulch, stakes, tree shelters, and signage are commonly used tools 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, two to four inches of organic mulch should be spread over the soil surface out to the dripline 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 recommend as mulches because they decompose rapidly and require more frequent application resulting in reduced benefits. Mulch has many benefits, including (CBF, 2001; ISA, 2003a):

- Prevents water evaporation
- Retains moisture
- 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 four inches of mulch may be applied, and a thinner layer of mulch should be applied if there is poor site drainage. Mulch should never be more than four inches deep or applied right next to the tree trunk. However, for reasons unknown, a common sight in many landscaped areas is the “mulch volcano,” shown in Figure 32. This overmulching technique can cause oxygen and moisture level problems, and cause decay of the living bark at the base of the tree. A mulch-free area, two to three inches wide at the base of the tree, is sufficient to avoid moist bark conditions and prevent decay (ISA, 2003a).

Figure 32. This mulch volcano (left) can cause the trunk to rot, compared with a properly mulched tree (right)

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 only be necessary for top-heavy trees or at sites where vandalism or windy exposure are a concern (Buckstrup and Bassuk, 2003; Doherty et al., 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 26 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 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 one year of planting (Doherty et al., 2003).

Tree Shelters
Tree shelters are two to five-foot tall plastic tubes that enclose seedlings to protect them from lawnmowers, weeds, wind, animals, drought and trampling (see Figure 21). 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 two to three 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 the summer and dead grasses in the 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; Sweeney, 1993; Palone and Todd, 1998). See Palone and Todd (1998) for sources of tree shelters and Hairston-Strang (2005) for instructions on installing tree shelters.

Signage
In most urban areas, the best protection for any reforestation project is installing signage to educate the public about the planting and increase visibility. Signage can help prevent unintentional trampling or mowing and educates the public about the purpose of the project. Figure 33 illustrates signage at an urban tree planting site.

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

6.4 Tree Inspection and Maintenance Techniques

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. For guidance on tree fertilization refer to (TCIA, 2004). 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 have not survived.

An inspection and maintenance schedule should be created for each reforestation site, and should include immediate post-planting inspection and maintenance and extend at least three to five 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 will typically be responsible for tree maintenance, while tree inspectors are normally a trained forester, arborist, or other professional who can diagnose tree health. A sample inspection schedule is provided in Table 21, and each activity is explained in further detail in the next section.

Table 21. Example Inspection and Maintenance Schedule					
Inspection and Maintenance Activity	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Perform regular inspections of 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:

- ❑ 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 (WDFW, 2002). After the first three 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 provided below:

- ❑ Assess tree vigor and overall health (see Greenfield et al., 1991 for guidance)
- ❑ Count the number of living trees and record species to determine survival rates
- ❑ Evaluate cause of mortality for dead trees and make recommendation for 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 (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 prior to planting
- Use storm water runoff at the site as a source of irrigation water where feasible (see Chapter 4)

Some rules of thumb for watering include:

- 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 each tree and site.

- A general horticultural rule of thumb is that trees need one inch of rainfall per week during the growing season (Petit et al., 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

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

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 et al., 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 is doing 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 as an option for weed control may be site limited and can inhibit natural regeneration between plantings. Mower strikes on trunks may be a problem unless trees are protected with mulch or tree shelters (Palone and Todd, 1998). If mowing is used, mow twice a year during the

first three growing seasons to a height of six inches but do not let weeds get higher than 12-14 inches before mowing (ACB, 2000; WDFW, 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 the late spring and in fall 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 two to four 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).

It is important to realize that 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 used to control populations of insect pests (Figure 34). 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 website: http://www.mdipm.umd.edu/.

References

ACB – See Alliance for the Chesapeake Bay.

Alliance for the Chesapeake Bay (ACB). 2000. Pennsylvania Stream ReLeaf Forest Buffer Toolkit. Harrisburg, PA: Pennsylvania Department of Environmental Protection.

Akbari, H.; Davis, S.; Dorsano, S.; Huang, J.; Winnett, S. 1992. Cooling Our Communities: A Guidebook on Tree Planting and Light-Colored Surfacing. Washington, DC: U.S. Environmental Protection Agency.

American Nursery and Landscape Association (ANLA). 2004. American Standard for Nursery Stock. ANSI Z60.1-2004. Washington, DC: American Nursery and Landscape Association. http://www.anla.org/applications/Documents/Docs/ANLAStandard2004.pdf (Accessed 2006).

Appleton, B.; Horsley, J.; Harris, V.; Eaton, G.; Fox, L.; Orband, J.; Hoysa, C. 2002. Trees for Parking Lots and Paved Areas. Publication No. 430-028. Blacksburg, VA: Virginia Cooperative Extension. http://www.ext.vt.edu/pubs/trees/430-028/430-028.html (Accessed 2006).

Bassuk, N.; Curtis, D. F.; Marranca, B. Z.; Neal, B. 2003. Recommended Urban Trees: Site Assessment and Tree Selection for Stress Tolerance. Ithaca, NY: Urban Horticulture Institute, Cornell University. www.hort.cornell.edu/uhi (Accessed 2006).

Buckstrup, M.; Bassuk, N. 2000. Transplanting success of balled-and burlapped versus bare-root trees in the urban landscape. Journal of Arboriculture 26(6): 298-308.

Buckstrup, M.; Bassuk, N. 2003. Creating the Urban Forest: The Bare Root Method. Ithaca, NY: Urban Horticulture Institute, Cornell University. http://www.hort.cornell.edu/department/faculty/bassuk/uhi/ (Accessed 2006).

Caraco, D. 2000. Keeping Soil in its Place. In: Schueler, T; Holland, H., eds. The Practice of Watershed Protection. Ellicott City, MD; 323-328.

CBF – See Chesapeake Bay Foundation.

Center for Watershed Protection (CWP). 2000a. The Compaction of Urban Soils. In: Schueler, T; Holland, H., eds. The Practice of Watershed Protection. Ellicott City, MD; 210-214.

Center for Watershed Protection (CWP). 2000b. Can Urban Soil Compaction Be Reversed? In: Schueler, T; Holland, H., eds. The Practice of Watershed Protection. Ellicott City, MD; 215-218.

Chapin, G. 2001. Recommended Trees for Vermont Communities. Waterbury, VT: Vermont Department of Forests, Parks & Recreation, Urban & Community Forestry Program.

Chesapeake Bay Foundation (CBF). 2001. Community Forest Buffer Guide. Annapolis, MD.

Chollak, T; Rosenfeld, P. 1998. Guidelines for Landscaping with Compost-Amended Soils. Redmond, WA: City of Redmond Public Works.

City of St. Louis. 2002. Informational Bulletin No. 8: Sidewalk and Sewer Damage. St. Louis, MO: City of St. Louis Department of Parks, Recreation, and Forestry, Forestry Division. http://stlouis.missouri.org/citygov/parks/forestry_div/SidewalknSewer.pdf (Accessed 2006).

City of Chicago. [N.d.]. City Trees – Selecting a Tree. http://www.cityofchicago.org/Environment/CityTrees/Selecting.html (Accessed 2005).

City of Seattle. [N.d.]. Street Tree Planting Procedures. Seattle, WA: Seattle Department of Transportation. www.cityofseattle.net/transportation/treeplanting.htm (Accessed 2006).

Cochran, J. 1997. Personal Communication. Emmitsburg, MD: U.S. Fire Administration.

Claytor, R.; Schueler, T. 1996. Design of Stormwater Filtering Systems. Ellicott City, MD: Center for Watershed Protection.

Coder, K. 2002. City Trees 38 (2). www.urban-forestry.com/citytrees/v32n2a09.html (Accessed 2005).

Costello, L.R.; Jones, K.S., eds. 2003. Reducing Infrastructure Damage by Tree Roots: A Compendium of Strategies. Cohasset, CA: Western Chapter of the International Society of Arboriculture.

Craul, P. J. [N.d.]. Urban Soils. Syracuse, NY: SUNY College of Environmental Science and Forestry. http://www.ces.ncsu.edu/fletcher/programs/nursery/metria/metria5/m57.pdf (Accessed 2006).

Craul, P. J. 1993. Urban Soils: An Overview and Their Future. In: Watson, G.W.; Neely, D., eds. The Landscape Below Ground: Proceedings of an International Workshop on

Tree Root Development in Urban Soils. Savoy, IL: International Society of Arboriculture.

Day, R. 1991. Damage of Structures Due to Tree Roots. Journal of Performance of Constructed Facilities. Reston, VA: American Society of Civil Engineers.

Department of Defense (DOD). 1996. Urban Forestry Manual. Department of Defense. https://www.denix.osd.mil/denix/Public/Library/Forestry/forestry.html (Accessed 2005).

DOD – See Department of Defense.

Dodge, L.; Geiger, J. 2001. Tree Roots and Sidewalk Damage. City Trees 37 (4).

Doherty, K.; Bloniarz, D.; Ryan, H. 2003. Positively the pits: successful strategies for sustainable streetscapes. Tree Care Industry 14(11): 34-42. http://www.umass.edu/urbantree/publications/pits.pdf (Accessed 2006).

Duiker, S. W. 2002. Diagnosing soil compaction using a penetrometer (soil compaction tester). Agronomy Facts 63. University Park, PA: Pennsylvania State University Department of Crop and Soil Sciences. http://cropsoil.psu.edu/extension/facts/agfacts63.cfm (Accessed 2006).

Environmental Concern, Inc. 2005. Wholesale Nursery Catalog: Native Wetland Plants. St. Michaels, MD: Environmental Concern, Inc.

Featherstone, A. 2000. Ecological restoration of natural forests: the two main approaches. Reforesting Scotland 23.

Flink, C.; Searns, R. 1993. Greenways: A Guide to Planning, Design, and Development. Arlington, VA: The Conservation Fund.

Flott, J. 2004. Proper Planting Begins Below Ground. TreeLink 19:1-4.

Foster, R. S. 1978. Bio-Engineering for the Urban Ecosystem. In: Metropolitan Tree Improvement Alliance Proceedings 1; 13-17.

Francis, J.K.; Parresol, B.P; de Patino, J.M. 1996. Probability of Damage to Sidewalks and Curbs by Street Trees in the Tropics. Journal of Arboriculture 22(4): 193-197.

Galli, J.; Vatovec, C.; Lecouteur, B. 2003. Draft Anacostia Tributary Exotic Invasive Plant Surveying Methodology and Indexing System. Metropolitan Washington Council of Governments.

Georgia Forestry Commission (GFC). 2001. Georgia Model Urban Forest Book. Macon, GA: Georgia Forestry Commission.

Georgia Forestry Commission (GFC). 2002. Community Tree Planting and Establishment Guidelines. Georgia Forestry Commission. Dry Branch, GA.

GFC – See Georgia Forestry Commission.

Gilman, E.F. 1997. Trees for Urban and Suburban Landscapes. Albany, NY: Delmar Publishers.

Grabosky, J.; Bassuk, N.; Trowbridge, P. 1999. Structural soils: a new medium to allow urban trees to grow in pavement. Landscape Architecture Technical Information Series. Washington, DC: American Society of Landscape Architects.

Greenfeld, J.; Herson, L.; Karouna, N.; Bernstein, G. 1991. Forest Conservation Manual: Guidance for the Conservation of Maryland's Forests During Land Use Changes, Under the 1991 Forest Conservation Act. Washington, DC: Metropolitan Washington Council of Governments.

Haber, E. 1997. Guide to Monitoring Exotic and Invasive Plants. Ottawa, ON: National Botanical Services.

Haefner, C.; Gannon, J.; Mushovic, T.; Nec, S.; Schrieber, P. 2002. Reclaiming Vacant Lots. Philadelphia, PA: The Pennsylvania Horticultural Society.

Hairston-Strang, A. 2005. Riparian Forest Buffer Design and Maintenance. Annapolis, MD: Maryland Department of Natural Resources.

Hammerschlag, R. S.; Sherald, J.L. 1985. Traditional and Expanded Tree Pit Concepts. In: METRIA 5: Proceedings of the Fifth Conference of the Metropolitan Tree Improvement Alliance. University Park, PA.

Harris, R. W.; Clark, J. R.; Matheny, N.P. 2004. Arboriculture: Integrated Management of Landscape Trees, Shrubs, and Vines. 4th ed. Upper Saddle River, NJ: Prentice Hall.

Head, C.; Robinson, F.; O'Brien, M. 2001. Best Management Practices for Community Trees: A Guide to Tree Conservation in Athens-Clarke County, Georgia. Athens, GA: Athens-Clarke County Unified Government.

Hobbs, E.R. 1988. Species richness of urban forest patches and implications for urban landscape diversity. Landscape Ecology 1(3): 141-152.

Huebner, C. D.; Olson, C.; Smith, H.C. 2004. Invasive Plants Field and Reference Guide: An Ecological Perspective of Plant Invaders of Forests and Woodlands. Morgantown, WV: USDA Forest Service. www.fs.fed.us/r9/wildlife/nnis/invasive-species-field-guide.pdf (Accessed 2006).

International Society of Arboriculture (ISA). 2005. Avoiding Excessive Soil over the Root Systems of Trees. Arborist News April 2005.

International Society of Arboriculture (ISA). 2003a. Proper Mulching Techniques. Champaign, IL: International Society of Arboriculture. http://www.treesaregood.com/treecare/mulching.aspx (Accessed 2006).

International Society of Arboriculture (ISA). 2003b. New Tree Planting. Champaign, IL: International Society of Arboriculture. http://www.treesaregood.com/treecare/tree_planting.aspx (Accessed 2006).

International Society of Arboriculture (ISA). 2000a. Tree Selection. Champaign, IL: International Society of Arboriculture. http://www.treesaregood.com/treecare/tree_selection.asp (Accessed 2006).

International Society of Arboriculture (ISA). 2000b. Buying High Quality Trees. Champaign, IL: International Society of Arboriculture. http://www.treesaregood.com/treecare/buying_highquality.asp (Accessed 2005).

Invasivespecies.gov. 2003. www.invasivespecies.gov. (Accessed 2006).

ISA – See International Society of Arboriculture.

Jensen, P. G.; Curtis, P. D.; Hamelin, D. L. 1999. Managing Nuisance Beavers Along Roadsides. A Guide for Highway Departments. Ithaca, NY: Cornell Cooperative Extension Publication.

Kays, B.L. 1985. Soils Assessments for Urban Tree Plantings. In: METRIA 5: Proceedings of the Fifth Conference of the Metropolitan Tree Improvement Alliance. http://www.ces.ncsu.edu/fletcher/programs/nursery/metria/metria5/m53.pdf (Accessed 2006).

Kochanoff, S., 2002. Trees vs. Power Lines: Priorities and Implications in Nova Scotia. Presented at the 5th Annual Canadian Urban Forest Conference. Markham, ON.

Kwon, H. K. 1996. The Return of the Beaver. Watershed Protection Techniques 2(3): 405-410.

Le Blanc, D. J. 1997. Environmental Assessment for the Management of Beaver Damage to Agriculture and Other Resources within the State of Louisiana. USDA Animal and Plant Health Inspection Service Wildlife Services.

Lemieux, N.; Maynard, B. 1999. GreenShare Factsheet: Deer Repellent. Kingston, RI: University of Rhode Island Department of Plant Sciences. http://www.uri.edu/ce/factsheets/sheets/deerrepel.html (Accessed 2006).

May, S. 2001. Management of Invasive Species in Restoration Projects. Land and Water 45(4). www.landandwater.com/features/vol45no4/vol45no4_1.html (Accessed 2006).

Maryland Department of the Environment (MDE). 2000. Maryland Stormwater Design Manual. Baltimore, MD: Maryland Department of the Environment.

Maryland State Highway Administration (MDSHA). [N.d.]. Woody Vegetation Management Standards. In: Integrated Vegetation Management Manual for Maryland Highways. www.sha.state.md.us (Accessed 2006).

MDE – See Maryland Department of the Environment.

MDSHA – See Maryland State Highway Administration.

Meyer, D. 1993. Tree shelters for seedling protection and increased growth. Forestry Facts 59. Madison, WI: University of Wisconsin Extension. http://forest.wisc.edu/extension/publications/59.pdf (Accessed 2006).

Miller, J. H. 2003. Nonnative Invasive Plants of Southern Forests: A Field Guide for Identification and Control. Asheville, NC: USDA Forest Service. www.invasive.org/eastern/srs/index.html (Accessed 2006).

Mock, T. 2003. Tales From the Trees: Nursery Tree Quality Grades and Standards. ArborAge. http://www.greenmediaonline.com/aa/2002/0210/0210tt.asp (Accessed 2006).

Morrow, S.; Smolen, M.; Stiegler, J.; Cole, J. 2002. Using Vegetation for Erosion Control. Landscape Architect 18(11): 54-57.

Muntean, D. 1997. Personal communication. Bellevue, WA.

Natural Resources Conservation Service (NRCS). 2002. Soil Quality and Site Assessment Cards. http://soils.usda.gov/sqi/files/CtcardsBW.pdf (Accessed 2006).

NCDENR – See North Carolina Department of Environment and Natural Resources.

Nebraska Forest Service. 2004. Storm Damage Bulletin No. 7: Tree Selection and Placement. http://www.nfs.unl.edu/CFA/TreeCare/Storm%20Damage%20Series.pdf (Accessed 2006).

New Jersey Department of Environmental Protection (NJDEP). 2000. Best Management Practices for Control of Nonpoint Source Pollution from Stormwater (Draft). NJDEP Division of Watershed Management. http://www.state.nj.us/dep/watershedmgt/DOCS/BMP_DOCS/chapter5_reparian_buffer.PDF (Accessed 2006).

NJDEP – See New Jersey Department of Environmental Protection.

North Carolina Department of Environment and Natural Resources (NCDENR). 2004. Guidelines for Riparian Buffer Restoration. Raleigh, NC: North Carolina Department of Environment and Natural Resources Ecosystem Enhancement Program. http://www.nceep.net/news/reports/buffers.pdf (Accessed 2006).

North Carolina Wetlands Restoration Program (NCWRP). [N.d.]. http://h2o.enr.state.nc.us/wrp/pdf/BidCharts/ (Accessed 2006).

Northern Virginia Regional Commission (NVRC). 1997. A Citizen's Guide to Tree Planting Projects in Northern Virginia. Annandale, VA: Northern Virginia Regional Commission.

NRCS – See Natural Resources Conservation Service.

NVRC – See Northern Virginia Regional Commission.

Octoraro Native Plant Nursery. 2004. Wholesale Nursery Catalog. Kirkwood, PA: Octoraro Native Plant Nursery.

Palone, R. S.; Todd, A. H. 1998. Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers. Radnor, PA: USDA Forest Service.

Partners for Fish and Wildlife Program (PFWP). 2001a. New York. Partners for Fish and Wildlife Program. http://partners.fws.gov/pdfs/pNY/pdf (Accessed 2006).

Partners for Fish and Wildlife Program (PFWP). 2001b. Rhode Island. Partners for Fish and Wildlife Program. Online: http://partners.fws.gov/pdfs/pRI.pdf (Accessed 2006).

PEL – See Pennsylvania Economy League.

Pennsylvania Economy League (PEL). 1995. Survey of the Costs Associated with Illegal Dumping in Philadelphia. Pennsylvania Economy League, Inc., Eastern Division. www.peleast.org/pubs2.htm#1995 (accessed 2005).

Pennsylvania State University (PSU). 1997. Forestry Fact Sheet #7: Questions About Trees and Utilities. University Park, PA: Pennsylvania State University College of Agricultural Sciences.

Pennypack Ecological Restoration Trust (PERT). [N.d.]. www.pennypacktrust.org/stewardship.htm (Accessed 2005).

PERT – See Pennypack Ecological Restoration Trust.

Petit, J.; Bassert, D. L.; Kollin, C. 1995. Building Greener Neighborhoods. Trees as Part of the Plan. Washington, DC: American Forests and the National Association of Homebuilders.

PFWP – See Partners for Fish and Wildlife Program.

Polomski, B.; Shaughnessy, D. 1999. Tree Selection. Clemson Extension Home and Garden Information Center Fact Sheet 1004. http://hgic.clemson.edu/facsheets/HGIC1004.htm (Accessed 2005).

PSU – See Pennsylvania State University.

Randrup, T.B.; McPherson, E. G.; Costello, L. R. 2001. Tree Root Intrusion in Sewer Systems: Review of Extent and Costs. Journal of Infrastructure Systems 7(1).

Redwood National and State Parks (RNSP). 2002. Exotic Plant Control Techniques. Redwood National and State Parks, CA. www.nps.gov/redw/eptech.htm (Accessed 2006).

RNSP – See Redwood National and State Parks.

Reynolds, M. K.; Ossenbruggen, H. S. 1999. Planting Trees in Designed and Built Community Landscapes: Checklists for Success. Concord, NH: State of New Hampshire, Department of Resources and Economic Development, Division of Forests and Lands, State Forester's Office.

Schueler, T.; Brown, K. 2004. Urban Stream Repair Practices. Version 1.0. Manual 4 of the Urban Subwatershed Restoration Manual Series. Ellicott City, MD: Center for Watershed Protection.

Sedbrook, J. 2005. Caring for Trees in a Dry Climate. Colorado State University/Denver County Cooperative Extension Master Gardener. http://www.colostate.edu/Depts/CoopExt/4DMG/Trees/caring.htm (Accessed 2006).

Shaw, D.; Schmidt, R. 2003. Plants for Stormwater Design. St. Paul, MN: Minnesota Pollution Control Agency.

Sheahan, M. 1998. Improving the conditions of native vegetation. In: VegNotes Series Two: Managing Native Vegetation. New South Wales Department of Infrastructure, Planning, and Natural Resources. http://www.dipnr.nsw.gov.au/nativeveg/publications/index.shtml (Accessed 2006).

Stahnke, G. 2004. Turfgrass Weed Control. Pacific Northwest Weed Control Handbook. Oregon State University. http://weeds.ippc.orst.edu/pnw/weeds (Accessed 2006).

Stenn, H. 2002. Guidelines and Resources for Implementing Soil Depth & Quality BMP T.5.13 in WDOE Western Washington Stormwater. Snohomish County Public Works Department. www.soilsforsalmon.org (Accessed 2006).

Sudbrock, Andy. 1996. Establishment of woodland groves for urban reforestation. Restoration and Reclamation Review. St. Paul, MN: University of Minnesota. http://hort.agri.umn.edu/h5015/rrr.htm (Accessed 2005).

Sweeney, B.W. 1993. Effects of Streamside Vegetation on Macroinvertebrate Communities of White Clay Creek in Eastern North America. In: Proceedings of the Academy of Natural Sciences of Philadelphia. Philadelphia, PA; 291-340.

TCIA – See Tree Care Industry Association.

TPHS – See The Pennsylvania Horticultural Society.

Tree Care Industry Association (TCIA). 2004. ANSI A300 Standards for Tree Care Operations. Tree Care Industry Association. http://www.natlarb.com/content/laws/a-300.htm (Accessed 2005).

Tree Trust. 2001. Community Tree Planting Guide. St. Paul, MN: Tree Trust. http://www.na.fs.fed.us/spfo/pubs/uf/treeguidehtm/intro.htm (Accessed 2006).

Trowbridge, P.; Bassuk, N. 2004. Trees in the Urban Landscape: Site assessment, Design, and Installation. Hoboken, NJ: John Wiley & Sons, Inc.

Tu, M.; Hurd, C.; Randall, J. M. 2001. Weed Control Methods Handbook: Tools and Techniques for Use in Natural Areas. The Nature Conservancy. http://tncweeds.ucdavis.edu/handbook.html (Accessed 2006).

Turner, H.K. 1998. Deer Protection and Control. Wildlife Habitats. http://www.wildlifehabitats.com/ohdeer.html (Accessed 2006).

United States Department of Agriculture Forest Service, Southern Region and Southern Research Station and Southern Group of State Foresters. 2005. Urban Forestry: A Manual for the State Forestry Agencies in the Southern Region. www.urbanforestrysouth.org/pubs/ufmanual/index.html (Accessed 2005).

United States Department of Agriculture (USDA). [N.d.]. Stewardship Incentive Program (SIP) – cost share rate structure guidance for SIP Practice 6: Riparian and Wetland Protection and Improvement for various states within the NE Area.

Unterschuetz, M. 1997. Personal communication. Wenatchee, WA.

Urban, J. 1992. Bringing Order to the Technical Dysfunction Within the Urban Forest. Journal of Arboriculture 18(2).

Urban, J. 1999. Room to Grow. Treelink 11:1-4.

USDA – See United States Department of Agriculture.

Van Driesche, R.; Blossey, B.; Hoddle, M.; Lyon, S.; Reardon, R. 2002. Biological Control of Invasive Plants in the Eastern United States. USDA Forest Service Forest Health Technology Enterprise Team.

VCE – See Virginia Cooperative Extension.

Virginia Cooperative Extension (VCE). 2002. Trees for Problem Landscape Sites. Publication No. 430-028. Blacksburg, VA: Virginia Cooperative Extension.

Washington Department of Fish and Wildlife (WDFW). 2002. Integrated Streambank Protection Guidelines. In: Aquatic Habitat Guidelines: An Integrated Approach to Marine, Freshwater and Riparian Habitat Protection and Restoration. Olympia, WA.

Watson, G.; Neely, D. 1994. The Landscape Below Ground – Proceedings of an International Workshop on Tree Root Development in Urban Soils. Savoy, IL: International Society of Arboriculture.

WDFW – See Washington Department of Fish and Wildlife.

Williston, H.; Balmer, W.; Tomczak, D. 1998. Managing the Family Forest in the South. Management Bulletin 8-MB1. Atlanta, GA: USDA Forest Service, Southern Region.

Wong, T.W., Good, J. E. G.; Denne, M. P. 1988. Tree Root Damage to Pavements and Kerbs in the City of Manchester. Arboricultural Journal 12: 7-34.

Appendix A: Urban Reforestation Site Assessment (URSA) Field Sheet

Urban Reforestation Site Assessment (URSA)

1. General Site Information

Location:

Property owner:

Current landuse:

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)

Micro-climate 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/noxious weeds present? Y/N

If Yes, note species and % coverage at site

Adjacent vegetative cover:

Is forest present? Y/N

If Yes, note dominant species:

Are invasive plants/noxious weeds present? Y/N

If Yes, note species and % 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

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 this section out for each bank individually

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 URSA has been conducted, the following tree selection guide can be used to narrow the field of possible choices for planting. This guide contains data about trees species that are considered suitable for a variety of settings in the urban environment and consists of two sections:

1. Environmental conditions
2. Tree characteristics

When planning an urban reforestation project, tree species can be selected using this guide based on their tolerance to environmental conditions at the site as well as any desired tree characteristics (e.g, small size for use near overhead wires). Tree species were selected based upon the overlap of their hardiness capability (described below) with the climate of the Mid-Atlantic and Northeast and Midwest U.S. regions as well as their ability to tolerate one or more variables typically associated with urban environments (e.g. salt tolerance, compaction).

The first chart displays information about the range of growing conditions for a given tree species and its tolerance to an array of environmental conditions. The second chart describes the physical attributes of each tree. The information about each species was derived from a variety of sources listed at the end of this appendix. When data elements were not fully available from these sources or elements were in conflict, other sources such as websites were queried to validate information.

When using the charts, it is important to 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. Consultation with local horticulturists, arborists, landscape architects or other natural resource professionals who are familiar with the geography and site specifics of the planting area will assist in refining the tree species selection and better assure success of the project.

Below are definitions of the fields used in the two charts.

Chart 1: Environmental Conditions

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 six hours of direct sunlight a day, partial shade plants tolerate direct sun for less than six hours a day or filtered light for most of the day, and full shade plants tolerate little or no direct sunlight or less than six 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 the 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.

Chart 2: Tree Characteristics

Height – The height is measure in feet from the base of the tree to the tip of the canopy.

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

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 is defines 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 four feet in depth 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; they are not recommended for use near open tile fields and irrigation systems. Taproots are the single thick root that grows straight into the soil to a depth of 15 feet or more. Plants with a sizeable taproot are considerable 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 U.S. 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 U.S. or southeast). Lastly, there are species that are not native or are cultivars. Non-native species were introduced to the U.S from other parts of the world, while cultivars are a by-product of breeding species for certain desired characteristics.

Fruit – Provides type of fruit and in some cases 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 Sources 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").

Parts of Chart 1 are marked with shaded boxes. A legend for the shading is provided below:

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

Literature Sources

Following are the primary sources of literature used in the compilation of the charts.

1. Bassuk N., D.F. Curtis, B. Marranca and B. Neal. 2003. Recommended Urban Trees: Site Assessment and Tree Selection for Stress Tolerance. Urban Horticulture Institute, Department of Horticulture, Cornell University, Ithaca, NY. 127 pp.

2. Center for Watershed Protection. 2004. Urban Tree Database, in progress. A compilation of information on characteristic of trees species derived from a number of resources.

3. Dirr, M.A. 1975. Manual of Woody Landscape Plants: their identification, ornamental characteristics, culture, propagation and uses, 5th Edition. Stipes Publishing, Champaign, IL. 1187 pp.

4. Hightshoe, G.L. 1988. Native Trees, Shrubs, and Vines for Urban and Rural America. Van Nostrand Reinhold, New York. 109 pp.

Other resources:

1. Little, E.L. 1980. The Audubon Society Field Guide to North American Trees, Eastern Region. Random House. New York. 714 pp.

2. Reynolds, M.K. and R.M. Boivin. 1994. Selecting Trees for Urban Landscape Ecosystems: Hardy Species for Northern New England Communities. State of New Hampshire, Department of Resources and Economic Development, Concord, New Hampshire. 104 pp.

Websites:

USDA, NRCS. 2004. The PLANTS Database, Version 3.5 (http://plants.usda.gov). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

USDA Fact Sheets 1994. (http://hort.ifas.ufl.edu/trees)

North Carolina State University Fact Sheets. http://www.
ces.ncsu.edu/depts/hort/consumer/factsheets.

Nowak, C. J. and P. R. O'Connor. 2001. Syracuse Urban Forest Master Plan: Guiding the City's Resource into the 21st Century. USDA Forest Service Northeastern Region. Gen. Tech. Rept. 287. This resource provides a list of tree species recommendations for given settings such as median strips of a certain width or parks.

http://www.fs.fed.us/ne/newtown_square/publications/technical_reports/pdfs/2001/gtrne287.pdf

University of Illinois Extension. Selecting Trees for Your Home.
http://www.urbanext.uiuc.edu/treeselector.

Appendix B: Urban Tree Selection Guide
Chart 1: Environmental Conditions

		Environmental Conditions															
Common Name	**Scientific Name**	**Hardiness Zone**	**Soil Moisture**				**Sun Exposure**			**Soil Components**			**Drought Tolerance**	**Flood Tolerance**	**Pest/Disease Tolerance**	**Soil Compaction**	**Salt Tolerance**	**pH level**
			Saturated or wet	Moist, well drained	Periods of dry	Prolonged drought	Full Sun	Partial Sun	Full Shade	Sand	Clay	Loam						
American basswood	Tilia americana	3 to 8	M	T	T	I	T	M	I	T	T	T	I	I	M	I	I	7.2 - 8.0
American beech	Fagus grandifolia	3 to 8	I	T	T	M	T	T	M	T	T	T	T	I	T	I	I	5.0 - 6.8
American elder	Sambucus canadensis	4 to 10	M	T	M	I	T	T	I	T	T	T	M	T	T	I	I	5.0 - 6.8
American elm (hybrids)	Ulmus hybrids	4 to 6	T	T	T	T	T	I	I	T	T	T	T	M	T	M	M	7.2 - 8.0
American hazelnut	Corylus americana	4 to 9	I	T	M	I	T	M	I	T	I	T	M	I	T	I	I	5.0 - 6.8
American Holly	Ilex opaca	5 to 6	M	T	M	I	T	T	T	T	T	T	T	M	T	T	T	5.0 - 6.8
American hophornbeam	Ostrya virginiana	3b to 9	I	T	M	I	T	M	I	T	M	T	I	I	T	T	I	5.0 - 6.8
American Hornbeam	Carpinus caroliniana	3 to 9	M	T	M	I	T	T	M	T	M	T	M	T	T	I	I	6.8 - 7.2
American Sycamore	Platanus occidentalis	3 to 9	T	T	M	I	T	I	I	M	M	T	T	T	M	T	I	5.0 - 6.8
Amur Maackia	Maackia amurensis	3 to 7	I	T	T	M	T	M	I	T	M	T	M	I	T	I	M	5.0 - 6.8

Appendix B: Urban Tree Selection Guide
Chart 1: Environmental Conditions

Common Name	Scientific Name	Hardiness Zone	Soil Moisture				Sun Exposure			Soil Components			Drought Tolerance	Flood Tolerance	Pest/Disease Tolerance	Soil Compaction	Salt Tolerance	pH level
			Saturated or wet	Moist, well drained	Period s of dry	Prolonged drought	Full Sun	Partial Sun	Full Shade	Sand	Clay	Loam						
Bald cypress	Taxodium distichum	5 to 10	T	T	T	I	T	I	I	T	T	T	M	T	T	T	M	6.8 - 7.2
Black Cherry	Prunus serotina	3 to 9	I	T	M	I	T	I	I	T	M	T	M	I	M	I	T	6.8 - 7.2
Black tupelo	Nyssa sylvatica	4 to 9	T	T	T	M	T	I	I	M	M	T	M	M	T	I	M	5.0 - 6.8
Black walnut	Juglans nigra	5 to 8	I	T	T	T	T	T	I	T	I	T	T	M	I	M	T	6.8 - 7.2
Black willow	Salix nigra	3 to 5	T	T	I	I	T	I	I	M	T	T	I	T	I	T	M	6.8 - 7.2
Blackhaw	Viburnum prunifolium	3b	I	M	T	T	T	M	I	M	I	M	T	I	M	I	I	7.2 - 8.0
Boxelder	Acer negundo	3 to 9	T	T	T	I	T	I	I	T	T	T	T	T	I	T	I	5.0 - 6.8
Bur Oak	Quercus macrocarpa	3 to 8	T	T	T	T	T	I	I	T	T	T	T	M	I	I	T	7.2 - 8.0
Butternut Hickory	Carya cordiformis	4 to 9	T	T	T	I	T	T	I	T	M	T	I	M	I	M	I	6.8 - 7.2
Buttonbush	Cephalanthus occidentalis	5 to 9	T	T	M	I	T	T	M	T	M	T	M	T	M		M	6.8 - 7.2

Appendix B: Urban Tree Selection Guide
Chart 1: Environmental Conditions

Common Name	Scientific Name	Hardiness Zone	Soil Moisture				Sun Exposure			Soil Components			Drought Tolerance	Flood Tolerance	Pest/Disease Tolerance	Soil Compaction	Salt Tolerance	pH level
			Saturated or wet	Moist, well drained	Period s of dry	Prolonged drought	Full Sun	Partial Sun	Full Shade	Sand	Clay	Loam						
Canada hemlock	Tsuga canadensis	3b to 7	I	T	M	I	M	T	T	T	I	T	I	I	I	I	I	6.8 - 7.2
Chestnut oak	Quercus prinus	4 to 8	I	T	T	I	T	M	I	M	I	T	M	T	M			6.8 - 7.2
Chinese Fringetree	Chionanthus retusus	5 to 9	I	T	T	T	T	T	M	T	M	T	T	I	T	I		6.8 - 7.2
Common chokeberry	Prunus virginiana	2 to 6	I	T	T	M	T	M	I	T	I	T	M	I	I	I	T	6.8 - 7.2
Common hackberry	Celtis occidentalis	3 to 9	I	T	T	I	T	M	I	T	I	T	I	M	I	M	T	7.2 - 8.0
Common spicebush	Lindera benzoin	4 to 9	I	T	M	I	T	T	I	T	M	T	I	T	T			7.2 - 8.0
Crabapple	Malus spp.	3 to 8	I	T	M	M	T	M	I	T	M	T	M	M	I		M	6.8 - 7.2
Crimeon linden	Tilia euchlora	3 to 7	I	T	T	I	T	I	I	T	I	T	M		M		I	7.2 - 8.0
Douglas fir	Pseudotsuga menziesii	4 to 6	I	T	T	I	T	M	I	M	M	T	I	M	I		I	6.8 - 7.2
Eastern cottonwood	Populus deltoides	3 to 9	T	T	T	T	T	M	I	T	T	T	T	T	I	T	T	6.8 - 7.2

Appendix B: Urban Tree Selection Guide
Chart 1: Environmental Conditions

Common Name	Scientific Name	Hardiness Zone	Soil Moisture				Sun Exposure			Soil Components			Drought Tolerance	Flood Tolerance	Pest/Disease Tolerance	Soil Compaction	Salt Tolerance	pH level
			Saturated or wet	Moist, well drained	Period s of dry	Prolonged drought	Full Sun	Partial Sun	Full Shade	Sand	Clay	Loam						
Eastern Hemlock	Tsuga canadensis	3b to 7	I	T	T	I	M	T	T	T	M	T	I	I	I	I	I	5.0 - 6.8
Eastern hophornbeam	Ostrya virginiana	3b to 9	I	T	T	I	T	M	I	T	I	T	I	I	T	I	I	7.2 - 8.0
Eastern larch	Larix laricina	2 to 4	M	T	T	M	T	M	I	M	M	T	T	M	I	T	T	5.0 - 6.8
Eastern Redbud	Cercis canadensis	4 to 9	I	T	T	I	T	M	M	T	I	T	I	M	T	M	M	6.8 - 7.2
Eastern redcedar	Juniperus virginiana	3b to 9	I	T	T	T	T	M	I	T	M	T	T	I	M	I	T	7.2 - 8.0
Eastern white pine	Pinus strobus	3 to 7	M	T	T	I	T	M	I	T	M	M	M	I	I	I	I	5.0 - 6.8
Elderberry*	Sambucus canadensis*	4 to 9	M	T	M	I	T	T	I	M	M	T	I	T	I			6.8 - 7.2
English Oak	Quercus robur	4 to 8	I	T	T	T	T	I	I	T	I	T	T	I	I		M	7.2 - 8.0
European Beech	Fagus sylvatica	4 to 7	I	T	T	I	T	M	I	T	I	T	M	I	M	I	I	5.0 - 6.8
European Hornbeam	Carpinus betulus	5 to 7	M	T	T	I	T	M	I	M	M	T	M		T	I	I	7.2 - 8.0
Flowering Dogwood	Cornus florida	5	I	T	T	I	M	T	T	T	I	T	M	T	I		I	6.8 - 7.2
Fringetree	Chionanthus virginicus	4 to 9	I	T	T	I	T	T	M	T	M	T	I	I	T	I	I	5.0 - 6.8

Appendix B: Urban Tree Selection Guide
Chart 1: Environmental Conditions

Common Name	Scientific Name	Hardiness Zone	Soil Moisture				Sun Exposure			Soil Components			Drought Tolerance	Flood Tolerance	Pest/Disease Tolerance	Soil Compaction	Salt Tolerance	pH level
			Saturated or wet	Moist, well drained	Period s of dry	Prolonged drought	Full Sun	Partial Sun	Full Shade	Sand	Clay	Loam						
Ginkgo	Ginkgo biloba (male only)	4 to 8	I	T	T	T	T	M	I	T	I	T	M	T	T		T	6.8 - 7.2
Golden rain tree	Koelreuteria paniculata	5	M	T	T	T	T	M	I	T	M	T	T		T		T	7.2 - 8.0
Gray Birch	Betula populifolia	3 to 6	M	T	T	I	T	I	I	T	T	T	M	T	I	M	T	6.8 - 7.2
Green Ash	Fraxinus pennsylvanica	4 to 9	M	T	T	I	T	M	I	T	M	T	M	T	I	T	M	6.8 - 7.2
Hawthorn	Crataegus viridis	4 to 7	M	T	T	T	T	I	I	T	M	T	T	M	I	T	M	7.2 - 8.0
Hazel Alder	Alnus serrulata	5 to 9	T	T	M	I	T	I	I	T	T	T	I	T	T	T	I	6.8 - 7.2
Hedge maple	Acer campestre	5 to 8	I	T	T	T	T	T	I	T	M	T	T		T	T	M	7.2 - 8.0
Highbush cranberry*	Viburnum trilobum*	2 to 7	I	T	M	I	T	T	I	M	M	T	M	T	M	T	M	5.0 - 6.8
Honeylocust	Gleditsia triacanthos inermis	4 to 9	I	T	T	T	T	M	I	M	M	T	T	M	I	T	T	7.2 - 8.0
Horsechestnut	Aesculus x carnea	5a	I	T	T	I	T	M	I		M	T	M		I	M	M	7.2 - 8.0
hybrid Elm	Ulmus hybrids	3 to 5	M	T	T	T	T	T	I	M	M	T	T	T	M	T	T	7.2 - 8.0

Appendix B: Urban Tree Selection Guide
Chart 1: Environmental Conditions

Common Name	Scientific Name	Hardiness Zone	Soil Moisture				Sun Exposure			Soil Components			Drought Tolerance	Flood Tolerance	Pest/Disease Tolerance	Soil Compaction	Salt Tolerance	pH level
			Saturated or wet	Moist, well drained	Period s of dry	Prolonged drought	Full Sun	Partial Sun	Full Shade	Sand	Clay	Loam						
Japanese tree lilac	Syringa reticulata	3 to 7	I	T	T	T	T	M	I	T	M	T	T	I	M		M	7.2 - 8.0
Japanese zelkova	Zelkova serrata	5 to 8	I	T	T	I	T	M	I	T	M	T	I		M	T	M	7.2 - 8.0
Katsura Tree	Cercidiphyllum japonicum	4 to 8	M	T	I	I	T	M	I	M	M	T	I		T	I	M	7.2 - 8.0
Laurel oak	Quercus laurifolia	6 to 9	T	T	T	I	T	T	I	T	M	T	M		T	T	I	6.8 - 7.2
Littleleaf Linden	Tilia cordata	3b to 7	I	T	T	I	T	M	I	T	I	T	M	T	I	M	I	7.2 - 8.0
Loblolly pine	Pinus taeda	6 to 9	M	T	T	I	T	I	I	T	M	T	M	M	M	T	I	5.0 - 6.8
London Planetree	Platanus x. acerifolia	5 to 8	T	T	T	T	T	T	M	T	M	T	T	M	I	T	M	7.2 - 8.0
Mountain ash	Sorbus cultivars	4 to 6	I	T	T	I	T	I	I	T	I	T	I	M	I	M		5.0 - 6.8
Mountain-laurel	Kalmia latifolia	4 to 9	I	T	M	I	M	T	M	T	M	T	I	I	I			5.0 - 6.8
Mugo Pine	Pinus mugo	3 to 7	I	T	M	I	T	T	I	M	M	T	M	T	I	T	T	7.2 - 8.0
Northern Red Oak	Quercus rubra	3b to 7	I	T	T	M	T	M	I	T	I	T	M	T	I	T	T	7.2 - 8.0
Nuttall oak	Quercus nuttallii	5 to 9	M	T	T	M	T	M	I	M	M	T	M	T	T	T	M	5.0 - 6.8

Appendix B: Urban Tree Selection Guide
Chart 1: Environmental Conditions

Common Name	Scientific Name	Hardiness Zone	Soil Moisture				Sun Exposure			Soil Components			Drought Tolerance	Flood Tolerance	Pest/Disease Tolerance	Soil Compaction	Salt Tolerance	pH level
			Saturated or wet	Moist, well drained	Period s of dry	Prolonged drought	Full Sun	Partial Sun	Full Shade	Sand	Clay	Loam						
Overcup oak	Quercus lyrata	5 to 9	T	T	T	M	T	T	I	T	T	T	T	T	T	T		5.0 - 6.8
Paperbark birch	Betula papyrifera	2 to 6	M	T	T	I	T	M	I	T	M	T	I	I	M	I	T	5.0 - 6.8
Pawpaw	Asimina triloba	5 to 8	I	T	M	I	T	T	M	T	I	T	I	I	T	I	M	6.8 - 7.2
Persimmon	Diospyros virginiana	4 to 9	I	T	T	M	T	T	M	T	I	M	T	M	M	M	M	5.0 - 6.8
Pin Oak	Quercus palustris	6 to 9	T	T	T	M	T	I	I	T	T	T	M		M	T	M	5.0 - 6.8
Pond Cypress	Taxodium ascendens	5 to 9	T	T	T	M	T	T	T	T	T	T	M	T	M		M	5.0 - 6.8
Red (slippery) elm	Ulmus rubra	3 to 9	M	T	T	M	T	T	T	T	M	T	M	T	T	T		6.8 - 7.2
Red Maple	Acer rubrum	3b to 9	T	T	T	I	T	T	M	T	T	T	I	T	I	T	I	5.0 - 6.8
Red-osier dogwood	Cornus sericea	2 to 7	T	T	M	I	T	T	I	M	T	T	M	T	M	T	I	6.8 - 7.2
River Birch	Betula nigra	3b to 9	T	T	T	I	T	M	I	T	T	T	I	M	M	T	I	5.0 - 6.8
Sassafras	Sassafras albidum	4 to 9	I	T	T	T	T	T	I	T	I	T	T	I	T	T	M	5.0 - 6.8

Appendix B: Urban Tree Selection Guide
Chart 1: Environmental Conditions

Common Name	Scientific Name	Hardiness Zone	Soil Moisture				Sun Exposure			Soil Components			Drought Tolerance	Flood Tolerance	Pest/Disease Tolerance	Soil Compaction	Salt Tolerance	pH level
			Saturated or wet	Moist, well drained	Period s of dry	Prolonged drought	Full Sun	Partial Sun	Full Shade	Sand	Clay	Loam						
Scarlet Oak	Quercus coccinea	4 to 9	I	T	T	T	T	M	I	T	I	M	T	I	T	I	M	5.0 - 6.8
Serviceberry	Amelanchier arborea	4 to 9	I	T	T	I	T	T	M	T	I	T	I	I	T	I	I	6.8 - 7.2
Shagbark hickory	Carya ovata	4 to 8	M	T	T	T	T	T	M	T	M	T	T	I	T	M	I	5.0 - 6.8
Shingle oak	Quercus imbricaria	4 to 8	I	T	T	M	T	M	I	T	M	T	M	M	T	M	M	5.0 - 6.8
Shumard oak	Quercus shumardii	5 to 9	M	T	T	M	T	M	I	T	I	T	M		T	T	M	7.2 - 8.0
Silky dogwood	Cornus amomum	4 to 8	T	T	T	M	M	T	M	T	I	T	M	T	T	T	I	5.0 - 6.8
Silver linden	Tilia tomentosa	4 to 7	I	T	T	I	T	M	I	T	I	T		T		M	M	7.2 - 8.0
Silver maple	Acer saccharinum	3 to 9	T	T	T	I	T	M	I	T	T	T	I	T	I	T	M	5.0 - 6.8
Smooth Sumac	Rhus glabra	3 to 9	I	M	T	T	T	M	I	T	M	T	T	T	T	I	T	6.8 - 7.2
Sourwood	Oxydendrum arboreum	5	I	T	T	I	T	T	M	T	I	T	M	I	T	I	M	6.8 - 7.2
Sugar Maple	Acer saccharum	4 to 8	I	T	T	I	T	T	M	T	I	T	I	I	I	I	I	6.8 - 7.2
Sugarberry	Celtis laevigata	5 to 9	M	T	T	I	T	M	I	T	M	T	M	T	M	T	T	6.8 - 7.2

Appendix B: Urban Tree Selection Guide
Chart 1: Environmental Conditions

Common Name	Scientific Name	Hardiness Zone	Soil Moisture				Sun Exposure			Soil Components			Drought Tolerance	Flood Tolerance	Pest/Disease Tolerance	Soil Compaction	Salt Tolerance	pH level
			Saturated or wet	Moist, well drained	Period s of dry	Prolonged drought	Full Sun	Partial Sun	Full Shade	Sand	Clay	Loam						
Swamp chestnut oak	Quercus michauxii	5 to 8	M	T	M	I	T	M	M	M	M	T	I	M	M	T		5.0 - 6.8
Swamp White oak	Quercus bicolor	4 to 8	M	T	T	I	T	T		M	T	T	I	M	T	T		6.8 - 7.2
Sweet-bay magnolia	Magnolia virginiana	5 to 9	T	T	M	I	T	T	M	T	T	T	I	T	T	T		5.0 - 6.8
Sweetgum	Liquidambar styraciflua	5 to 9	M	T	T	I	T	M	I	T	T	T	I	T	T	T	M	6.8 - 7.2
Trident Maple	Acer buergeranium	5 to 8	I	T	T	M	T	I	I	T	I	T	M		T	M	M	5.0 - 6.8
Tulip Tree	Liriodendron tulipifera	4 to 9	M	T	T	I	T	T	M	T	M	T	I	I	T	I	I	5.0 - 6.8
Water hickory	Carya aquatica	5 to 9	T	T	T	I	T	T	I	T	M	T	M	T	T	T	I	6.8 - 7.2
White Ash	Fraxinus americana	4 to 9	M	T	T	I	T	T	M	T	M	T	I	M	I	M	M	6.8 - 7.2
White oak	Quercus alba	3b to 9	I	T	T	I	T	T	M	T	T	T	M	I	I	I	T	5.0 - 6.8
Willow Oak	Quercus phellos	5 to 9	M	T	T	T	T	T	M	T	T	T	T	M	I	T	I	6.8 - 7.2
Winterberry	Illex verticillata	3 to 5	T	T	T	I	T	T	M	T	T	T	M	I	M	T	I	5.0 - 6.8
Witch hazel	Hammamelis virginiana	3b to 8	I	T	T	I	I	M	T	M	M	T	I	I	T	I	I	5.0 - 6.8

Appendix B: Urban Tree Selection Guide
Chart 2: Tree Characteristics

	TREE CHARACTERISTICS											
Common Name	Scientific Name	Height (ft.)	Canopy Spread (ft.)	Growth Rate	Form/Habit	Root Structure	Native to U.S.	Fruit	Seasonal Foliage Color		Flower	
									Summer	Fall	Blooming Season	Characteristics
American basswood	Tilia americana	50 to 80	35 to 50	medium	youth: pyramidal, mature:oval & rounded	deep lateral	native	nutlet	green	yellow	summer	light yellow, fragrant, not showy
American beech	Fagus grandifolia	50 to 75	40 to 60	slow	oval, pyramidal, symmetrical	shallow lateral	native	nut	green	copper	spring	yellow, not showy
American elder	Sambucus canadensis	8 to 12	6 to 10	fast	upright vase canopy, multiple stems	shallow lateral	native	berry, purple-black	green	yellow	summer	white, showy
American elm (hybrids)	Ulmus hybrids	50 to 70	40 to 60	fast	varies with cultivar	shallow & deep lateral	native	samara, disc-shaped	green	yellow	spring	green, not showy
American hazelnut	Corylus americana	8 to 15	6 to 10	medium	straight, spreading, ascending branches	shallow lateral	native	nut	green	brown	spring	white on long stalks, showy
American holly	Ilex opaca	40 to 50	15 to 25	slow	pyramidal, symmetrical	shallow lateral	native	berry, red	green	green	spring	white, not showy

Appendix B: Urban Tree Selection Guide
Chart 2: Tree Characteristics

	TREE CHARACTERISTICS											
Common Name	**Scientific Name**	**Height (ft.)**	**Canopy Spread (ft.)**	**Growth Rate**	**Form/Habit**	**Root Structure**	**Native to U.S.**	**Fruit**	**Seasonal Foliage Color**		**Flower**	
									Summer	Fall	Blooming Season	Characteristics
American hophornbeam	Ostrya virginiana	30 to 50	20 to 30	slow	oval to rounded, horizontal drooping branches	deep lateral & taproot	native	pods, small, greenish-white inflated in hanging clusters	dark green	yellow	spring (female), winter (male)	dioecious, male flower is showy
American hornbeam	Carpinus caroliniana	30 to 50	20 to 35	slow	horizontal, pyramidal to vase, symmetrical	deep lateral	native	nutlet	green	orange, red, yellow	spring	orange, yellow, not showy
American sycamore	Platanus occidentalis	75 to 90	50 to70	fast	rounded, spreading, pyramidal	shallow lateral	native	syncarp, round, bristly	green	yellow, not showy	spring	red, not showy
Amur maackia	Maackia amurensis	20 to 35	15 to 25	slow	rounded, vase shape, symmetrical	shallow lateral	not native	pod	green	green, not showy	summer	white, showy
Bald cypress	Taxodium distichum	50 to 70	20 to 40	medium	pyramidal, buttressed trunk at base	shallow lateral	native	cone, small	green	orange -brown	spring	brown, not showy

Appendix B: Urban Tree Selection Guide
Chart 2: Tree Characteristics

	TREE CHARACTERISTICS											
Common Name	Scientific Name	Height (ft.)	Canopy Spread (ft.)	Growth Rate	Form/Habit	Root Structure	Native to U.S.	Fruit	Seasonal Foliage Color		Flower	
									Summer	Fall	Blooming Season	Characteristics
Black cherry	Prunus serotina	60 to 90	35 to 50	fast	oval	deep lateral, taproot	native	cherry, small, dark red, nearly black, produces fruit litter	dark green	yellow-red	spring	white, showy
Black tupelo	Nyssa sylvatica	30 to 60	20 to 40	medium	pyramidal or irregular-round, dense branching	taproot	native	berry, bluish, small, produces fruit litter	green	orange-red, variable	spring with leaves	green-white, not showy
Black walnut	Juglans nigra	70 to 90	60 to100	medium	open, rounded	taproot	native	seed housed in green or brown 1-2" husk, produces fruit litter	green	yellow	spring	green, not showy
Black willow	Salix nigra	60 to 100	20 to 35	fast	straight trunk, upright branches, narrow	shallow lateral	native	capsule, small, with cottony seeds	green	yellow - brown	spring	yellow, not showy
Blackhaw	Viburnum prunifolium	15 to 20	10	medium	small tree or shrub, short trunk, rounded	deep lateral	native	berry, blue-black	green	red, shiny	spring	white, showy, small

Appendix B: Urban Tree Selection Guide
Chart 2: Tree Characteristics

	TREE CHARACTERISTICS											
Common Name	**Scientific Name**	**Height (ft.)**	**Canopy Spread (ft.)**	**Growth Rate**	**Form/Habit**	**Root Structure**	**Native to U.S.**	**Fruit**	**Seasonal Foliage Color**		**Flower**	
									Summer	Fall	Blooming Season	Characteristics
Boxelder	Acer negundo	30 to 50	40 to 60	fast	rounded, multi-stemmed branching	deep lateral	native	samara, profuse, produces fruit litter	light green	yellow-green to brown	spring	yellow-green, not showy
Bur Oak	Quercus macrocarpa	60 to 80	60 to 90	slow	large trunk, broadly rounded, open	taproot	native	acorn, fringed cap, produces fruit litter	dark green	dull yellow-green	spring, with leaves	yellow, not showy
Butternut hickory	Carya cordiformis	60 to 80	30 to 40	slow	tall trunk, broad, rounded	taproot	native	nut, produces fruit litter	yellow-green	yellow- gold	spring, with leaves	green, not showy
Buttonbush	Cephalanthus occidentalis	6 to 12	6 to 10	slow	shrub, rounded, loosely branched	lateral	native	nutlets	dark green	evergreen	summer	white, showy
Canada hemlock	Tsuga canadensis	40 to 70	25 to 35	medium	pyramidal, branches pendulous	shallow lateral	native	cone	dark green	evergreen	summer	yellow-green, not showy

Appendix B: Urban Tree Selection Guide
Chart 2: Tree Characteristics

	TREE CHARACTERISTICS											
Common Name	Scientific Name	Height (ft.)	Canopy Spread (ft.)	Growth Rate	Form/Habit	Root Structure	Native to U.S.	Fruit	Seasonal Foliage Color		Flower	
									Summer	Fall	Blooming Season	Characteristics
Chestnut oak	Quercus prinus	60 to 70	30 to 50	medium	rounded and relatively dense branching	lateral	native	acorn, produces fruit litter	yellow-green	orange-yellow to yellow-brown	spring	yellow-green, not showy
Chinese fringetree	Chionanthus retusus	15 to 25	10 to 25	slow	small tree, rounded, multi-stemmed	lateral	non-native	berry, blue	green, leathery	yellow	spring	white, showy, fragrant
Common chokeberry	Prunus virginiana	20 to 30	18 to 25	fast	oval to upright small tree, spreading	shallow lateral	native	berry, red to dark purple	dark green	yellow	spring	white, showy
Common hackberry	Celtis occidentalis	40 to 60	60 to 70	medium	rounded with pendulous branches	deep lateral	native	berry, orange-red	green	yellow, yellow-green	spring, with leaves	not showy
Common spicebush	Lindera benzoin	6 to 12	6 to 10	slow	rounded shrub	lateral	native	berry, scarlett	light green, fragrant	yellow to gold	spring, before leaves	dioecious, yellow-green, small, somewhat showy in early spring

Appendix B: Urban Tree Selection Guide
Chart 2: Tree Characteristics

	TREE CHARACTERISTICS											
Common Name	**Scientific Name**	**Height (ft.)**	**Canopy Spread (ft.)**	**Growth Rate**	**Form/Habit**	**Root Structure**	**Native to U.S.**	**Fruit**	**Seasonal Foliage Color**		**Flower**	
									Summer	Fall	Blooming Season	Characteristics
Crabapple	Malus spp.	16 to 30	8 to 35	medium	rounded, upright to weeping, varies	lateral	varies	berry, red, small, produces fruit litter	varies	varies	spring	white to pink, showy, fragrant
Crimeon linden	Tilia euchlora	40 to 60	20 to 30	medium	pyramidal to rounded, densely branched	lateral	non-native	nutlets, small	dark green	green to yellow-green	summer	yellow fragrant, showy
Douglas fir	Pseudotsuga menziesii	40 to 80	12 to 20	medium	pyramidal crown, densely branched	lateral	non-native to mid-Atlantic or NE	cone, pendulous	green	evergreen	summer	not showy
Eastern cottonwood	Populus deltoides	75 to 100	50 to 75	fast	vase-shaped, spreading branches	shallow lateral	native	capsule, opens with cottony seeds	medium green	yellow	spring, before leaves	greenish catkins, not showy
Eastern hemlock	Tsuga canadensis	40 to 70	25 to 35	medium	pyramidal, branches pendulous	shallow lateral	native	cone, small	dark green	evergreen	summer	not showy

Appendix B: Urban Tree Selection Guide
Chart 2: Tree Characteristics

	TREE CHARACTERISTICS											
Common Name	Scientific Name	Height (ft.)	Canopy Spread (ft.)	Growth Rate	Form/Habit	Root Structure	Native to U.S.	Fruit	Seasonal Foliage Color		Flower	
									Summer	Fall	Blooming Season	Characteristics
Eastern hophornbeam	Ostrya virginiana	30 to 50	20 to 30	slow	rounded, horizontal, drooping branches	deep lateral, taproot	native	pods, greenish-white in tight clusters	dark green	yellow	spring/ winter	not showy
Eastern larch	Larix laricina	40 to 80	15 to 30	medium	pyramidal, open, drooping branches	shallow lateral	native	cone	blue-green	yellow	spring	not showy
Eastern redbud	Cercis canadensis	20 to 30	25 to 35	medium	spreading, open branching	shallow lateral	native	pods	early leaves purplish then green	yellow to golden	spring, before leaves	purple-pink, showy
Eastern redcedar	Juniperus virginiana	40 to 50	8 to 20	slow	densely pyramidal	taproot	native	cones, greenish blue, glaucous	sage green	evergreen	winter to spring	not showy, dioecious
Eastern white pine	Pinus strobus	50 to 80	20 to 40	medium	broadly pyramidal, horizontal branches	deep lateral	native	cones, pendant	bluish green,	evergreen	summer	not showy

Appendix B: Urban Tree Selection Guide
Chart 2: Tree Characteristics

	TREE CHARACTERISTICS											
Common Name	Scientific Name	Height (ft.)	Canopy Spread (ft.)	Growth Rate	Form/Habit	Root Structure	Native to U.S.	Fruit	Seasonal Foliage Color		Flower	
									Summer	Fall	Blooming Season	Characteristics
Elderberry	Sambucus canadensis	5 to 12	4 to 6	fast	shrub, multiple stemmed, spreading branches	lateral	native	berry, blue in clusters	dark green	yellow-green	summer	white to cream, showy
English oak	Quercus robur	40 to 60	40 to 60	slow	massive tree with short trunk, broadly round	lateral	not native	acorn	dark green	brown	spring with leaves	not showy
European Beech	Fagus sylvatica	50 to 60	35 to 45	slow	pyramidal to rounded, low branches	shallow lateral	not native	husk, small, covered with bristles	dark green	red to gold	spring with leaves	not showy
European hornbeam	Carpinus betulus	40 to 60	30 to 40	slow	rounded	lateral	not native	nutlets in pendulous cluster	dark green	yellow to yellow green	spring	not showy
Flowering dogwood	Cornus florida	20 to 30	20 to 30	medium	rounded, low branching	shallow	native	berry, red cluster	dark green	red to red-purple	spring	white, showy

Appendix B: Urban Tree Selection Guide
Chart 2: Tree Characteristics

	TREE CHARACTERISTICS											
Common Name	Scientific Name	Height (ft.)	Canopy Spread (ft.)	Growth Rate	Form/Habit	Root Structure	Native to U.S.	Fruit	Seasonal Foliage Color		Flower	
									Summer	Fall	Blooming Season	Characteristics
Fringetree	Chionanthus virginicus	12 to 15	10 to 15	slow	shrub, large,open spreading habit	deep lateral	native	berry, blue	green	yellow-brown to golden	spring	white, showy, fragrant
Ginkgo	Ginkgo biloba (male only)	50 to 60	30 to 40	slow	pyramidal, open, wide-spreading branches	lateral	not native	not applicable to male trees	green	yellow	spring	not showy, dioecious
Golden rain tree	Koelreuteria paniculata	30 to 40	30 to 40	medium	irregular rounded, open	deep lateral	not native	capsule, green to brown	green to blue-green	yellow	summer	yellow clusters, showy
Gray birch	Betula populifolia	40 to 50	30 to 40	medium	pyramidal	shallow lateral	native	nutlet, small	dark green	yellow	spring	catkins, not showy
Green ash	Fraxinus pennsylvanica	40 to 60	30 to 50	fast	rounded	shallow lateral	native	samara-like	green	yellow	spring with leaves	not showy, dioecious, flower litter problem

Appendix B: Urban Tree Selection Guide
Chart 2: Tree Characteristics

	TREE CHARACTERISTICS											
Common Name	Scientific Name	Height (ft.)	Canopy Spread (ft.)	Growth Rate	Form/Habit	Root Structure	Native to U.S.	Fruit	Seasonal Foliage Color		Flower	
									Summer	Fall	Blooming Season	Characteristics
Hawthorn	Crataegus viridis	20 to 25	12 to 35	slow	rounded to vase-shaped	shallow lateral	native	berry, red	green	scarlet to purple	spring	white clusters, showy
Hazel alder	Alnus serrulata	6 to 20	4 to 15	fast	small tree, multi-stemmed	shallow lateral	native	cone-like, small	green	yellow-brown	winter to early spring	yellow-brown catkins, in late winter
Hedge maple	Acer campestre	25 to 35	25 to 35	slow	rounded, low branching	shallow lateral	not native	samara	dark green	yellow	spring	green, not showy
Highbush cranberry	Viburnum trilobum	8 to 12	8 to 12	medium	large shrub, upright spreading, multi-stemmed	shallow lateral	native, upper north-east	berry, red	dark green	yellow to red-purple	spring	white, showy
Honeylocust	Gleditsia triacanthos inermis	40 to 80	30 to 70	fast	rounded, spreading,	shallow lateral, taproot	natural-ized	pod, long brown, produces fruit litter	light green	yellow-brown	summer	not showy

Appendix B: Urban Tree Selection Guide
Chart 2: Tree Characteristics

	TREE CHARACTERISTICS											
Common Name	**Scientific Name**	**Height (ft.)**	**Canopy Spread (ft.)**	**Growth Rate**	**Form/Habit**	**Root Structure**	**Native to U.S.**	**Fruit**	**Seasonal Foliage Color**		**Flower**	
									Summer	Fall	Blooming Season	Characteristics
Horsechestnut (red)	Aesculus x carnea	35 to 50	30 to 45	slow	rounded, dense branching	shallow lateral	not native	nut, glossy, somewhat prickly	dark green	yellow-brown	spring	pink to red clusters, showy
Hybrid elm	Ulmus hybrids	50 to 70	40 to 60	varies with cultivar	varies with cultivar	shallow lateral	not native	samara, small	green	yellow	late winter to spring	greenish-red, not showy
Japanese tree lilac	Syringa reticulata	20 to 25	15 to 20	slow	oval, spreading, densely branched	lateral	not native	capsule	dark green	yellow-brown	summer	cream, showy, fragrant
Japanese zelkova	Zelkova serrata	50 to 80	50 to 75	medium	vase-shaped, spreading branches	lateral	not native	berry, small	green	yellow-orange to red	spring	not showy
Katsura tree	Cercidiphyllum japonicum	40 to 60	25 to 60	fast	rounded	shallow lateral	not native	pods, small in clusters	bluish-green	yellow to orange	spring before leaves	not showy

Appendix B: Urban Tree Selection Guide
Chart 2: Tree Characteristics

	TREE CHARACTERISTICS											
Common Name	**Scientific Name**	**Height (ft.)**	**Canopy Spread (ft.)**	**Growth Rate**	**Form/Habit**	**Root Structure**	**Native to U.S.**	**Fruit**	**Seasonal Foliage Color**		**Flower**	
									Summer	Fall	Blooming Season	Characteristics
Laurel oak	Quercus laurifolia	60 to 70	35 to 45	fast	oval, densely branched	lateral	native	acorn	green	yellow	spring	not showy
Littleleaf linden	Tilia cordata	50 to 70	30 to 50	medium	oval to rounded, densely branched	deep lateral	not native	nutlet	dark green	yellow green to yellow	summer	yellow pendant clusters, fragrant, showy
Loblolly pine	Pinus taeda	60 to 90	30	fast	oval to rounded, branches horizontal	shallow taproot, lateral	native	cone	green	evergreen	summer	not showy
London Planetree	Platanus x. acerifolia	70 to 100	65 to 80	medium	open and spreading	shallow	not native	syncarp, bristly, rounded, produces fruit litter	green	yellow-brown	spring	not showy
Mountain ash	Sorbus cultivars	15 to 25	15 to 25	medium	varies with cultivar	lateral	not native	berry, orange-red	green	varies	spring	white clusters, showy

Appendix B: Urban Tree Selection Guide
Chart 2: Tree Characteristics

	TREE CHARACTERISTICS											
Common Name	**Scientific Name**	**Height (ft.)**	**Canopy Spread (ft.)**	**Growth Rate**	**Form/Habit**	**Root Structure**	**Native to U.S.**	**Fruit**	**Seasonal Foliage Color**		**Flower**	
									Summer	Fall	Blooming Season	Characteristics
Mountain-laurel	Kalmia latifolia	3 to 15	3 to 15	slow	large shrub, symmetrical	lateral	native	capsule	dark green	evergreen	spring	white to deep rose, showy
Mugo pine	Pinus mugo	15 to 20	20 to 25	slow	prostrate or pyramidal	deep lateral	not native	cone	yellow-green	evergreen	summer	not showy
Northern red oak	Quercus rubra	40 to 60	40 to 60	medium	rounded, open	lateral, short taproot	native	acorn, produces fruit litter	green to blue-green	brown	spring with leaves	not showy
Nuttall oak	Quercus nuttallii	60 to 80	40 to 50	fast	oval, open	shallow lateral	native to central US	acorn, produces slight fruit litter	green	red	spring	not showy
Overcup oak	Quercus lyrata	40 to 60	35 to 60	medium	rounded	lateral	native	acorn, produces fruit litter	dark green	yellow-brown	spring with leaves	not showy

Appendix B: Urban Tree Selection Guide
Chart 2: Tree Characteristics

	TREE CHARACTERISTICS											
Common Name	**Scientific Name**	**Height (ft.)**	**Canopy Spread (ft.)**	**Growth Rate**	**Form/Habit**	**Root Structure**	**Native to U.S.**	**Fruit**	**Seasonal Foliage Color**		**Flower**	
									Summer	Fall	Blooming Season	Characteristics
Paperbark birch	Betula papyrifera	50 to 70	25 to 50	medium	rounded, low branching	lateral	native	nutlet	dark green	yellow	spring before leaves	not showy
Pawpaw	Asimina triloba	15 to 20	15 to 20	medium	shrub/small tree, rounded crown	deep lateral	native	berry, yellow turning brown/black, produces fruit litter	green	yellow to yellow green	spring with leaves	purple, not showy
Persimmon	Diospyros virginiana	30 to 60	20 to 35	slow	rounded crown	taproot	native	berry, yellow to pale orange	dark green	yellow-green to red-purple	spring	white, fragrant, somewhat showy
Pin oak	Quercus palustris	50 to 70	40 to 50	medium	oval-pyramidal	shallow lateral	native	acorn, produces fruit litter	dark green	bronze to red	spring	not showy
Pondcypress	Taxodium ascendens	70 to 80	15 to 20	slow	conical	taproot	native to the S.E.	cone	green	orange-brown	spring	not showy

Appendix B: Urban Tree Selection Guide
Chart 2: Tree Characteristics

	TREE CHARACTERISTICS											
Common Name	**Scientific Name**	**Height (ft.)**	**Canopy Spread (ft.)**	**Growth Rate**	**Form/Habit**	**Root Structure**	**Native to U.S.**	**Fruit**	**Seasonal Foliage Color**		**Flower**	
									Summer	Fall	Blooming Season	Characteristics
Red (slippery) elm	Ulmus rubra	50 to 80	40 to 60	medium	vase-shaped	lateral	native	samara	dark green	yellow	spring before leaves	not showy
Red maple	Acer rubrum	35 to 60	30 to 70	medium	varies with cultivar	shallow lateral	native	samara	green	yellow, orange, red	spring before leaves	red, showy
Red-osier dogwood	Cornus sericea	7 to 9	7 to 10	fast	broad-spreading shrub	shallow lateral	native	berry, white	green	purple to red	spring	white, showy
River birch	Betula nigra	40 to 50	30 to 40	fast	pyramidal to oval, multi-stemmed	shallow lateral	native	nutlet	green	yellow	spring before leaves	not showy
Sassafras	Sassafras albidum	30 to 60	25 to 40	medium	rounded	taproot	native	berry, dark blue	green	yellow to orange to red	spring	yellow, showy

Appendix B: Urban Tree Selection Guide
Chart 2: Tree Characteristics

	TREE CHARACTERISTICS											
Common Name	**Scientific Name**	**Height (ft.)**	**Canopy Spread (ft.)**	**Growth Rate**	**Form/Habit**	**Root Structure**	**Native to U.S.**	**Fruit**	**Seasonal Foliage Color**		**Flower**	
									Summer	Fall	Blooming Season	Characteristics
Scarlet Oak	Quercus coccinea	70 to 75	40 to 50	medium	rounded	taproot	native	acorn, produces some fruit litter	dark green	scarlet	spring	not showy
Serviceberry	Amelanchier arborea	20 to 30	15 to 25	medium	oval, multi-stemmed	shallow lateral	native	samara	green	varies	spring	greenish-yellow, showy
Shagbark hickory	Carya ovata	60 to 80	25 to 35	slow	oblong	taproot	native	nuts encased in hard-shelled husk, produces fruit litter	yellow-green	yellow to golden brown	spring with leaves	not showy
Shingle oak	Quercus imbricaria	60 to 70	40 to 50	slow	rounded, open	taproot	native	acorn, produces fruit litter	dark green	red to scarlet	spring with leaves	not showy
Shumard oak	Quercus shumardii	60 to 80	45 to 65	medium	rounded	taproot	native	acorn, produces some fruit litter	dark green	yellow to red	spring with leaves	not showy

Appendix B: Urban Tree Selection Guide
Chart 2: Tree Characteristics

	TREE CHARACTERISTICS											
Common Name	**Scientific Name**	**Height (ft.)**	**Canopy Spread (ft.)**	**Growth Rate**	**Form/Habit**	**Root Structure**	**Native to U.S.**	**Fruit**	**Seasonal Foliage Color**		**Flower**	
									Summer	Fall	Blooming Season	Characteristics
Silky dogwood	Cornus amomum	6 to 10	6 to 10	medium	shrub, rounded, multi-stemmed	shallow lateral	native	berry, blue	dark green	green to reddish purple	spring	yellowish-white, showy
Silver linden	Tilia tomentosa	50 to 70	35 to 55	medium	pyramidal, densely branched	shallow lateral	not native	nutlet	dark green	green-yellow to yellow	summer	yellow, clusters, fragrant, showy
Silver maple	Acer saccharinum	50 to 70	30 to 50	fast	rounded, spreading	shallow lateral	native to S.E.	samara	green, silvery	yellow-brown	spring	greenish, yellow to red, some showy
Smooth Sumac	Rhus glabra	10 to 15	10 to 15	fast	shrub/small tree, spreading	shallow lateral	native	berry, deep red, cluster	dark green	yellow to orange-red	summer	green-yellow, not showy
Sourwood	Oxydendrum arboreum	40 to 60	30 to 35	slow	varies	deep lateral	native	capsule, brown	dark green	yellow, red to purple	summer	white, fragrant, showy

Appendix B: Urban Tree Selection Guide
Chart 2: Tree Characteristics

	TREE CHARACTERISTICS											
Common Name	**Scientific Name**	**Height (ft.)**	**Canopy Spread (ft.)**	**Growth Rate**	**Form/Habit**	**Root Structure**	**Native to U.S.**	**Fruit**	**Seasonal Foliage Color**		**Flower**	
									Summer	Fall	Blooming Season	Characteristics
Sugar maple	Acer saccharum	45 to 50	35 to 40	slow	rounded	shallow lateral	native	samara	green	yellow, orange to red	spring before leaves	yellow clusters, somewhat showy
Sugarberry	Celtis laevigata	60 to 80	60 to 80	medium	rounded, spreading branches	shallow lateral	native	berry, orange-red to blue-black, produces short-term fruit litter	green	yellow	spring	not showy
Swamp chestnut oak	Quercus michauxii	60 to 70	30 to 50	medium	rounded	lateral	native	acorn, produces fruit litter	green	brown to dark red	spring	not showy
Swamp white oak	Quercus bicolor	50 to 60	50 to 60	slow	broad, open	shallow lateral	native	acorn, produces some fruit litter	dark green	yellow, red-purple	spring	not showy
Sweet-bay magnolia	Magnolia virginiana	10 to 20	10 to 20	medium	shrub/small tree, loose, open	shallow lateral	native	aggregate of red berry-like fruits	dark green	yellow to yellow brown, semi-evergreen	spring, ongoing	creamy white, fragrant, showy

Appendix B: Urban Tree Selection Guide
Chart 2: Tree Characteristics

	TREE CHARACTERISTICS											
Common Name	**Scientific Name**	**Height (ft.)**	**Canopy Spread (ft.)**	**Growth Rate**	**Form/Habit**	**Root Structure**	**Native to U.S.**	**Fruit**	**Seasonal Foliage Color**		**Flower**	
									Summer	Fall	Blooming Season	Characteristics
Sweetgum	Liquidambar styraciflua	50 to 75	40 to 65	medium	rounded	lateral, taproot	native	aggregate of stiff capsules, produces fruit litter	green	yellow, orange, red, purple	spring with leaves	not showy
Trident maple	Acer buergeranium	20 to 25	20 to 25	slow	rounded, low branching, bonsai potential	lateral	not native	samara	dark green	yello, orange, red	spring	not showy
Tulip tree	Liriodendron tulipifera	70 to 90	35 to 50	fast	oval crown	shallow and deep lateral	native	cluster of woody samaras	green	yellow	spring	pale green with orange, showy
Water hickory	Carya aquatica	50 to 65	30 to 40	fast	oval	taproot	native to the S.E.	seeds in a thin husk, produces fruit litter	dark green	yellow to golden brown	spring before leaves	not showy
White Ash	Fraxinus americana	50 to 70	40 to 60	medium	rounded	shallow lateral	native	samara	dark green	yellow to purple	spring	not showy

Appendix B: Urban Tree Selection Guide
Chart 2: Tree Characteristics

	TREE CHARACTERISTICS											
Common Name	**Scientific Name**	**Height (ft.)**	**Canopy Spread (ft.)**	**Growth Rate**	**Form/Habit**	**Root Structure**	**Native to U.S.**	**Fruit**	**Seasonal Foliage Color**		**Flower**	
									Summer	Fall	Blooming Season	Characteristics
White oak	Quercus alba	60 to 100	50 to 90	slow	broad rounded, spreading	taproot	native	acorn, produces some fruit litter	gray green	red to scarlet	spring	not showy
Willow oak	Quercus phellos	40 to 60	30 to 60	medium	rounded	shallow lateral	native	acorn, produces some fruit litter	dark green	yellow, brown, red	spring with leaves	not showy
Winterberry	Illex verticillata	6 to 10	6 to 10	slow	shrub, rounded, densely branched	shallow lateral	native	berry, red	green	yellow	spring	white clusters, showy
Witch hazel	Hammamelis virginiana	10 to 12	12 to 18	medium	shrub, irregular, spreading branches	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 $____
7. Total Cost		***$***____	