Urban Watershed Forestry Manual

Part 1: Methods for Increasing Forest Cover in a Watershed

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Prepared by:

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

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

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ABOUT THIS MANUAL SERIES

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

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

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

Part 3: Urban Tree Planting Guide provides detailed guidance on urban tree planting that is applicable at both development site and watershed scales. Topics covered include site assessment, planting design, site preparation, and other pre-planting considerations, and planting and maintenance techniques. An Urban Tree Database 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.

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- Karen Cappiella
- Tom Schueler
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- Chris Swann
- Tiffany Wright

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Chapter 1: Introduction to Urban Watershed Forestry

This chapter introduces urban watershed forestry concepts, and makes the case as to why communities should integrate trees and forests into their planning practice in both developed and developing watersheds. Included are a discussion of terminology, principles, goals, objectives, and techniques related to urban watershed forestry; a review of the impacts of urbanization on forests and watershed health; a review of the watershed benefits of forest cover; and unique considerations for reforesting urban areas.

What Is Urban Watershed Forestry?

Since the 1980's, urban forest research and new technical analysis tools have defined a wider role and value for urban trees. There is greater recognition of how urban trees and forests improve air and water quality, reduce storm water runoff, conserve energy, and protect public health. Increasingly, these benefits are being better defined and quantified through scientific research. At the same time, the loss of trees and forests in developing watersheds continues, and urban tree canopy in inner cities deteriorates through removal or lack of replacement. The rate of conversion of forests to urban uses increased twofold from 1982 to 2001 in the United States, reinforcing the need for greater integration of forest and land use planning (NRCS, 2001).

The magnitude of impacts due to the loss of green space in urban watersheds, such as increased runoff and impervious cover, demonstrates the vital role of forestry in urban watershed management. Past approaches to restoring urban watersheds that have relied on structural solutions have failed to protect and restore urban streams. Many practitioners in the engineering community are now turning to vegetation and natural systems as a critical part of the solution; however, bringing these approaches together has not always been easy.

Urban watershed forestry is an integration of the fields of urban and community forestry and watershed planning. ***Urban and community forestry*** is the management of the urban forest for environmental, community, and economic benefits, while ***watershed planning*** promotes sound land use and resource management to improve water resources within a watershed. Therefore, urban watershed forestry sets watershed-based goals for managing the urban forest as a whole rather than managing forest resources on a site-by-site or jurisdictional basis, and provides strategies for incorporating forests into urban watershed management.

This integration of urban forestry techniques into urban watershed management acknowledges the importance of trees and forests in protecting water resources. This approach encourages watershed managers and urban foresters to systematically assess existing urban forests to determine how best to manage them to meet watershed protection and restoration goals. Several important terms related to the concept of urban watershed forestry are defined in the next section.

Terminology of Urban Watershed Forestry

It is important to distinguish the terms "forest," "forest cover," "urban forest cover," and "urban tree canopy." The terms are similar, yet each is defined, measured, and classified in a different manner by different authorities. These terms have confounding definitions and may even be used interchangeably. Box 1 gives examples.

BOX 1. SEEING THE FOREST FOR THE TREES

The Pacific Forest Trust defines a **forest** as "a biological community of plants and animals that is dominated by trees and other woody plants" (PFT, 2004). While at first glance this definition appears adequate, it may be difficult to use it to define which portions of an urban watershed are covered by forest.

Forest cover can be defined as the total area of land that is classified as forest. Just because an area is classified as forest, however, does not necessarily mean that it is 100% covered by trees. So how many trees constitute a forest? By delving deeper into the existing literature and resources on the mapping and classification of forests, one discovers a diverse array of operational definitions, such as the following examples:

1. "Dense forest" includes areas with **more than 70% canopy cover,** while "fragmented forest" includes areas with 40% to 70% cover. – *The Tropical Ecosystem Environment Observations by Satellite (TREES) project (Center for International Forestry Research, 2004).*

2. "Forest" consists of areas dominated by trees with a total **canopy cover of 61% or more**, tree crowns usually interlocking. – *National GAP Analysis (USGS, 2000).*

3. "Forest" consists of trees with their crowns overlapping, generally forming **60% to 100% cover** (as opposed to "woodlands" which have 25% to 60% cover). – *The U.S. National Vegetation Classification System (TNC, 1998).*

4. "Closed forest" includes areas with **more than 40% canopy cover**, while "open or fragmented forest" includes areas with 10% to 40% cover. – T*he United Nations Environment Programme (Center for International Forestry Research, 2004)*.

Since the sources cited above define tree cover as ranging from 40% to more than 70%, estimates of watershed forest cover will vary greatly depending on which classification system is used.

Since the methods in this manual apply to urban watersheds, what we are really concerned with measuring is **urban forest cover**. This manual deals primarily with forests, trees and shrubs, and does not address planting herbaceous vegetation. "Urban forest" is defined as trees growing individually, in small groups or under forest conditions, on public and private lands, in cities and towns and their suburbs (CBP, 2004). Therefore, our working definition of urban forest cover includes individual trees and groups of trees, as well as forests. The best measure of urban forest cover is attained by mapping the urban tree canopy.

Urban tree canopy is defined as the layer of tree leaves, branches, and stems that cover the ground when viewed from above (CBP, 2004). Measuring tree canopy is also important because it is the tree canopy that provides such benefits as rainfall interception, pollutant removal, and shading of streams and impervious surfaces (Box 2).

The term "forest cover" will be used throughout this manual when describing the recommended methodology (e.g., measure forest cover in the watershed, set numerical goals for forest cover in the watershed). **For the purposes of this manual, our operational definition of forest cover is the total area of land that is classified as forest by the land cover data source you are using.** The ideal land cover data recommended for this analysis is urban tree canopy, which includes individual trees and groups of trees, as well as forest. We recognize, however, that this level of detail may not be attainable for all communities. Therefore, communities conducting an assessment of their urban forests should use the best available data.

BOX 2. MEASURING URBAN TREE CANOPY

Exhibit A. Forest cover derived from land use data

Exhibit B. Urban tree canopy derived from satellite imagery

Measurement of forest cover in an urban watershed is further confounded by forest fragmentation. Small forest fragments may not meet the canopy coverage requirements for forest cover and thus may be classified as nonforest cover. Therefore, the scale at which forest cover is measured and the resolution of the data are also important. Exhibits A and B illustrate this point. Note the presence of small patches of trees in Exhibit B compared with the lower resolution forest cover data in Exhibit A.

An assessment of urban tree canopy may be obtained from existing data or images such as USGS digital orthoquads or IKONOS satellite imagery. Minimum standards for measuring urban tree canopy include a resolution of 1 meter and imagery that is no more than 3 years old (CBP, 2004). One difficulty with mapping urban tree canopy in urban areas is that these assessments may underestimate tree cover where buildings cast shadows over the trees.

Urban tree canopy generally gives a more accurate representation of forest cover in an urban watershed than a forest cover layer. The assessment approach used by a community, however, will be driven by the funds and technical capacity of the staff, as well as by the availability of modeling applications for the data. If it is not feasible to map urban tree canopy, the highest-resolution forest cover data available should be used. Be sure to check the metadata to determine the scale, resolution, and recency of the data.

Watersheds are land areas that drain surface water and ground water to a downstream water body or outlet, such as a river, lake, or estuary. Watershed drainage areas vary in size, but urban watershed forestry generally deals with watersheds ranging from 20 to 100 square miles or more. Given their size, they may encompass many political jurisdictions, contain a mix of land uses (forest, agricultural, rural, suburban, urban), and have a broad range of pollution sources. Each watershed is composed of a number of smaller watersheds called subwatersheds.

Subwatersheds, as a general rule of thumb, have a drainage area less than 10 square miles and include streams ranging from first to third order. Ideally, each step in the urban watershed forestry methodology outlined in this manual would be conducted at the *subwatershed* scale. However, this may not be feasible or desirable for communities that wish to conduct urban forest assessments or land use planning at a larger scale. For this reason, and for simplicity, this manual presents each step at the *watershed* scale. Many of the techniques related to urban watershed forestry are actually implemented at the parcel scale. A ***parcel*** is a contiguous plot of land that is owned by a single entity.

Urban watersheds or subwatersheds are defined for the purposes of this manual, as having more than 10% total impervious cover. ***Impervious cover*** includes any surface that does not allow water to infiltrate, such as roads, buildings, parking lots, and driveways. Natural channels and hydrologic processes in urban watersheds are often altered by the creation of impervious cover as well as by structural features such as storm drains, channelized streams, and retention basins.

Storm water treatment practices (STPs) include a suite of structural practices that treat storm water runoff before it enters local receiving waters. STPs treat runoff by capturing and temporarily detaining water, allowing pollutants to settle out. Major categories of STPs include ponds, wetlands, infiltration systems, filtering systems, and open channel systems. Additional detail on specific STPs and how trees can be incorporated is provided in Part 2 of this manual series.

Principles of Urban Watershed Forestry

Urban watershed forestry takes a new approach to watershed protection and restoration by systematically tracking and managing forest cover at the watershed level. The basic aim is to *reduce forest loss and maximize forest gains over time*. Some of the core principles of this emerging practice are listed below.

1. Forest cover is the highest and best use of land in a watershed, and is superior to turf grass as a vegetative cover in terms of water storage, groundwater recharge, runoff reduction, pollutant reduction, and habitat (see Watershed Benefits of Forest Cover later in this chapter, for a description of benefits).

2. Forest cover provides additional environmental benefits by reducing ozone and other air quality problems, reducing the “urban heat island effect” and providing habitat for urban wildlife.

3. Urban forests are a dynamic mosaic of forest, impervious, and turf cover, are highly impacted by outside stressors, such as air pollution, invasive species, and construction damage.

4. The constant changes in watershed forest, impervious, and turf cover needs to be carefully analyzed over time to track gains and losses as a result of development, forest conservation and afforestation.

5. Special management techniques are needed to improve urban forest quality, measured in terms of diversity, structure, canopy, maturity, species composition, and relationship to natural ecosystems.

6. Existing forest tracts should be investigated to identify those that have the greatest priority for permanent conservation or need for special management techniques.

7. Forest loss during land development can be sharply reduced by employing local planning and forest conservation tools.

8. Forest cover gains can be sharply increased through systematic reforestation of larger parcels of public or corporate lands, and by tree planting on smaller privately owned individual parcels. Forest canopy can also be enhanced through the addition of trees to the built environment, such as within storm water treatment practices and along streets and other engineered settings.

9. Land use plans should contain explicit goals with respect to watershed forest cover and impervious cover. The two are interrelated and the ultimate impervious cover expected in the watershed can be used to define realistic forest cover goals.

10. Urban watershed forestry should be integrated with other watershed restoration practices, such as stream repair and restoration, storm water retrofits, and pollution prevention practices.

11. Urban reforestation efforts should focus on improving conditions at the planting site, selecting appropriate species, and designing the reforestation plan to maximize long-term survival of the forest.

Goals of Urban Watershed Forestry

Based on the preceding principles, urban watershed forestry has three goals:

1. ***Protect*** undeveloped forests from human encroachment and the impacts of land development by creating and applying various planning techniques, regulatory tools, and incentives. This includes conservation easements that protect forested land from being developed, land use planning that directs development away from forested areas and reduces imperviousness, ordinances that require developers to physically protect selected forests during construction, and financial incentives--such as storm water credits--that encourage developers to conserve more forest at a development site.

2. ***Enhance*** the health, condition, and function of urban forest fragments. This includes the use of various techniques for increasing and improving structure, hydrologic function, diversity, and wildlife habitat, and improving conditions for tree growth to ensure long-term sustainability of the forest.

3. ***Reforest*** open land through active replanting or natural regeneration to regain some of the functions and benefits of a forest and to increase overall watershed forest cover and increase forest canopy.

Objectives of Urban Watershed Forestry

The three goals of urban watershed forestry are achieved by pursuing the major objectives described in Table 1.

Table 1. Urban Watershed Forestry Objectives, by Goal		
Goal	Objective	Description
1. Protect	A. Protect Priority Forests	Select large tracts of currently unprotected and undeveloped forest to protect from future development.
	B. Prevent Forest Loss During Development and Redevelopment	Directly or indirectly reduce forest clearing during construction.
	C. Maintain Existing Forest Canopy	Prevent clearing and encroachment on existing protected and unprotected forest fragments on developed land.
2. Enhance	D. Enhance Forest Fragments	Improve the structure and function of existing protected forests.
3. Reforest	E. Plant Trees During Development and Redevelopment	Require on-site reforestation as a condition of development.
	F. Reforest Public Land	Systematically reforest feasible planting sites within public land, rights-of-way, or other priority sites.
	G. Reforest Private Land	Encourage tree planting on feasible locations within individual yards or property.

Techniques of Urban Watershed Forestry

Chapter 3 provides detailed information on 29 specific techniques that can be implemented to meet the goals and objectives of urban watershed forestry. Considerations for planting trees during development and redevelopment are covered in more detail in Part 2 of this manual series, Conserving and Planting Trees at Development Sites.

Why Is Urban Watershed Forestry Important?

Over 75% of the U.S. population lives in cities (Nowak and others, 2000). As a result, more and more people are disconnected from natural resources such as forests that support them and the watersheds in which they live. As a result, urban residents may take for granted the important benefits provided by urban trees. Urban watershed forestry represents an important management approach, given the many benefits provided by urban forests and impact of development on forest structure and function and watershed health. Managing urban forests in ways that explicitly address watershed health can mitigate some of the negative impacts of forest fragmentation, soil compaction, and increased impervious cover in urban watersheds.

An overview of the watershed benefits of urban forests, the impacts of impervious cover on watershed health, the impacts of urbanization on forests, and the unique properties of the urban planting environment is provided below.

Watershed Benefits of Forest Cover

Forests provide numerous benefits that can be divided into those that affect watershed health and those that are more apparent at the individual parcel scale. These benefits can be further categorized into economic, environmental, and community benefits. These benefits are summarized in Table 2.

Table 2. Economic, Environmental, and Community Benefits of Trees		
Scale	**Category**	**Benefit**
Watershed	Environmental	• Reduce storm water runoff • Improve regional air quality • Reduce stream channel erosion • Improve soil and water quality • Provide habitat for terrestrial and aquatic wildlife • Reduce summer air and water temperatures
Parcel	Economic	• Decrease heating and cooling costs • Reduce construction and maintenance costs (by decreasing costs related to clearing, grading, paving, mowing, and storm water management) • Increase property values • Positively influence consumer behavior
	Environmental	• Reduce urban heat island effect • Enhance function of storm water treatment practices
	Community	• Increase livability • Improve health and well-being • Block UV radiation • Provide shade • Buffer wind and noise • Increase recreational opportunities • Provide esthetic value

Part 2 of this manual series addresses the benefits trees provide at the individual parcel scale (e.g., development sites). A description of the watershed benefits of forest cover follows and is summarized in Table 3. Box 3 introduces methods to place an economic value on these watershed benefits, while Box 4 describes various forest conditions that maximize these watershed benefits.

BOX 3. CALCULATING THE VALUE OF TREES

Recent studies have attempted to place a value on the watershed benefits provided by urban trees. American Forests has conducted more than 20 studies known as Regional Ecosystem Analyses. These analyses use satellite imagery to estimate forest loss over time and CITYgreen software to place an economic value on lost forest. American Forests analyzed the Baltimore-Washington area and estimated a decline in tree cover from 51% to 37% from 1973 to 1997. The loss in forest cover produced an estimated 19% increase in storm water runoff (from each 2-year peak storm event) (American Forests, 1999). The cost to construct storm water treatment practices to intercept this runoff would cost $1.08 billion (American Forests, 1999). The lost tree canopy would have removed about 9.3 million pounds of pollutants from the atmosphere annually, at a value of approximately $24 million per year (American Forests, 1999).

Table 3. Watershed Benefits of Forest Cover	
Benefit	**Description**
Reduce storm water runoff and flooding	• Trees intercept rainfall in their canopy, reducing the amount of rain that reaches the ground. A portion of this intercepted rainwater evaporates from tree surfaces. This effect is greater in low rainfall events. • Trees take up water from the soil through their roots during transpiration, which increases soil water storage potential and lengthens the amount of time before rainfall becomes runoff • Trees promote infiltration by attenuating runoff and by increasing soil drainage due to the creation of macropores by tree roots. The addition of organic matter (e.g., leaf litter) also increases storage of water in the soil, further reducing runoff. • Reduced runoff from forested land reduces the frequency and volume of downstream flood events.
Improve regional air quality	• Trees absorb nitrogen dioxide, carbon monoxide, ozone, and particulate matter from the atmosphere. • Trees reduce air temperature which reduces formation of pollutants that are temperature dependent, such as ozone • Trees indirectly improve air quality by cooling the air, storing carbon, and reducing energy use, which reduces power plant emissions
Reduce stream channel erosion	• Trees growing along a stream bank prevent erosion by stabilizing the soil with root systems and the addition of organic matter, and by substantially dispersing raindrop energy • Reduced runoff volume due to forests upstream can reduce downstream flood flows that erode the stream channel
Improve soil and water quality	• Trees prevent erosion of sediment by stabilizing soil with root systems and the addition of organic matter, and by substantially dispersing raindrop energy • Trees take up nutrients such as nitrogen from soil and groundwater • Forested areas can filter sediment and associated pollutants from runoff • Certain tree species break down pollutants commonly found in urban soils, groundwater, and runoff, such as metals, pesticides and solvents
Provide habitat for terrestrial and aquatic wildlife	• Forests (and even single trees) provide habitat for wildlife in the form of food supply, interior breeding areas, and migratory corridors • Streamside forests provide habitat in the form of leaf litter and large woody debris, for fish and other aquatic species • Forest litter, such as branches, leaves, fruits, and flowers, form the basis of the food web for stream organisms
Reduce summer air and water temperatures	• Riparian forests shade the stream and regulate summer air and water temperatures, which is critical for many aquatic species • Trees and forests shade impervious surfaces, reducing temperature of storm water runoff, which can ameliorate the thermal shocks normally transmitted to receiving waters during storms.

BOX 4. MAXIMIZING WATERSHED BENEFITS

While trees and shrubs provide watershed benefits, certain forest conditions maximize the benefits. The location of forests within headwater riparian areas in the watershed is one of these conditions. Headwater streams (e.g., first or second order) are often the most sensitive to development as well as the least protected. Cumulatively, headwater streams make up 75% of the total stream and river mileage in the country (Schueler, 1995); therefore, having an intact forested riparian corridor along headwater streams can provide significant benefits to overall watershed health.

At the site level, large, mature trees and a continuous canopy provide the most benefit in terms of storm water reduction, cooling, and wildlife habitat (Metro, 2002). Proper site preparation, planting, and management techniques are essential to ensure that newly planted trees live long enough to mature and provide these benefits. Tree selection and strategic placement can also be critical to attaining benefits. Urban watershed forestry goals should seek to expand the forested riparian corridor along headwater streams, conserve existing tracts of contiguous forest, connect existing forest parcels, increase canopy cover in urban areas, and maintain long-term forest health.

Reduce storm water runoff

Forests improve stream quality and watershed health primarily by decreasing the quantity of storm water runoff and pollutant loads that reach surface waters. Trees reduce storm water runoff through **rainfall interception** by the tree canopy (Box 5), by releasing water into the atmosphere through **evapotranspiration** (Box 6), and by promoting **infiltration** of water through the soil and storage of water in the soil and forest litter (Box 7). Figure 1 illustrates these hydrological processes.

Reducing storm water runoff improves watershed health by recharging groundwater and improving baseflow in streams, decreasing flooding and erosion, and reducing the pollutants that are washed into streams from impervious surfaces. Forests can absorb or store the majority of rainfall from most storms and, therefore, have lower runoff coefficients than do turf grass or impervious cover (see Appendix A). The **runoff coefficient** is the proportion of rainfall that is converted to storm water runoff.

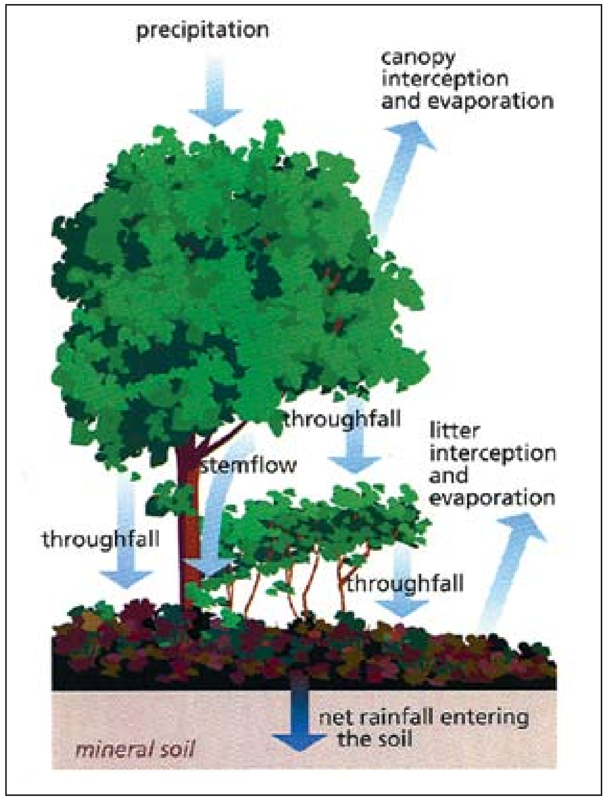


Figure 1. Schematic of a Tree's Hydrologic Cycle (Source: FISRWG, 1998, p. 2-5)

BOX 5. RAINFALL INTERCEPTION

Rainfall interception is the capture of rainwater by leaves, branch surfaces, mosses, and bark. Interception decreases throughfall of rain and reduces runoff volume and velocity. **Throughfall** is the portion of precipitation that reaches the ground directly through gaps in the tree canopy, or dripping from leaves, twigs, and stems (Metro, 2002). Intercepted rainwater is either evaporated directly into the atmosphere, absorbed by the canopy surfaces or transmitted to the ground via stems, branches, and other tree surfaces (referred to as **stemflow)**. The ability of a

(continued)

RAINFALL INTERCEPTION (CONT'D)

tree to intercept rainfall is influenced by its branching structure, canopy density, leaf texture, and bark texture (Metro, 2002). A key factor in determining the amount of leaf coverage or canopy density of trees is the **Leaf Area Index**, the ratio of leaf area to ground area (ITRC, 2001).

Studies of rainfall interception for individual trees indicate that a mature deciduous tree can intercept from 500 to 760 gallons of water per year (Envirocast, 2003; CUFR, 2001), and a mature evergreen can intercept more than 4,000 gallons per year (Portland BES, 2000; CUFR, 2001). Rainfall interception for individual trees ranges from 10% to 68% of a rainfall event (CMHC, no date; ITRC, 2001; Passmore, no date), and is dependent on the tree species and rainfall characteristics. Studies of rainfall interception by forests estimate that between ten and 40% of incoming rainfall is intercepted by forest canopy (Watershed Science Center, 2000). Canopy interception in conifer stands ranges from 15% to 40% of annual precipitation, and interception in hardwood stands ranges from 10% to 20% (Xiao and others, 2000). Rainfall interception is higher for evergreens because they have the ability to intercept rainfall all year round.

BOX 6. EVAPOTRANSPIRATION

Evapotranspiration (ET) represents the combined water loss due to evaporation from soil and plant surfaces and transpiration by plants. **Transpiration** is the process by which plants take up water from the soil through their root system and release moisture in the form of water vapor from their leaves. The uptake of soil water by tree roots increases soil water storage potential, effectively lengthening the amount of time before rainfall becomes runoff. Many factors influence transpiration rates, including leaf shape, size, number of pores (stomata), and waxiness of the leaf surface (Metro, 2002). Generally speaking, evergreens have lower transpiration rates because they are more efficient than deciduous trees at retaining moisture, due to the structure of their leaves (Metro, 2002). Chart 1 presents typical ET rates for different types of trees in an urban environment (adapted from Perry, 1994).

In general, a mature tree can transpire 100 gallons per day (Akbari and others, 1992; Metro, 2002). Water-loving species such as bald cypress can absorb 880 gallons per day, depending on soil type and saturation (Keating, 2002). An acre of mature forest can take up more than 1,800 gallons of water every day (Envirocast, 2003).

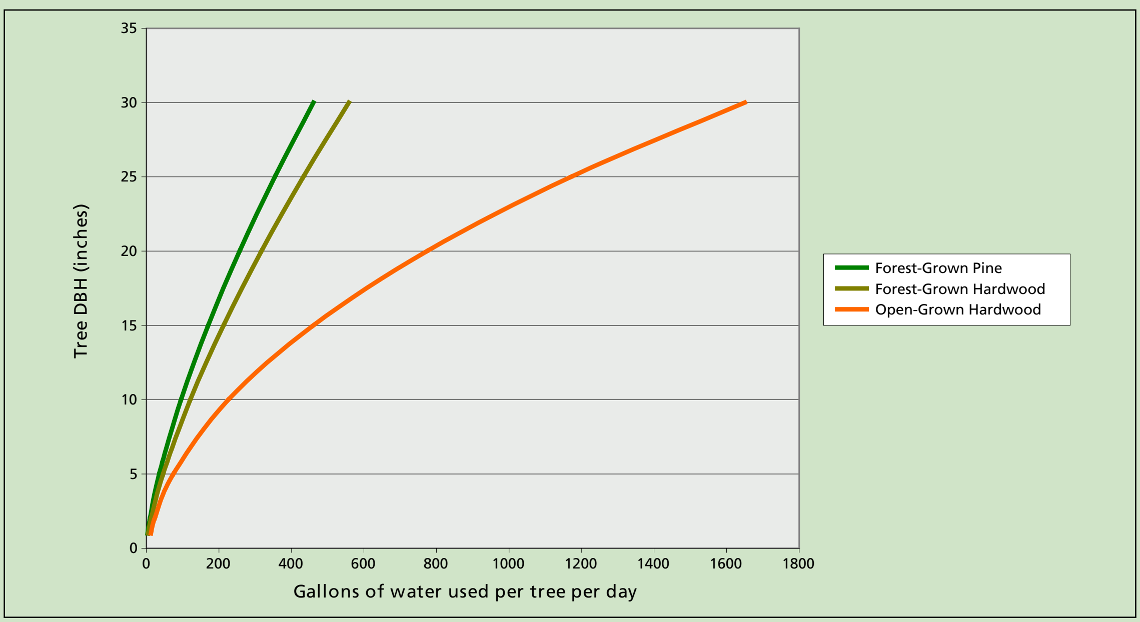


Chart 1: Evapotranspiration Rates for Various Tree Types (adapted from Perry, 1994)

BOX 7. INFILTRATION

The presence of trees helps to slow down or attenuate storm water runoff, which promotes infiltration of water through the soil. In addition, tree roots and organic matter from leaf litter create soil conditions that increase the capacity to infiltrate rainfall, which further reduces the volume of water that runs off the land surface. Tree roots increase infiltration by creating interconnected pathways in the soil called macropores. The depth, size, and number of these macropores, as well as the storm event characteristics, determine how much macropores aid infiltration during storms. Leaf litter and other organic matter produced by trees also work to reduce the amount of runoff by holding water and promoting infiltration rather than allowing rainfall to run off the surface as overland flow. This organic matter provides a good environment for earthworms, which also improve infiltration through the creation of additional macropores.

Infiltration tests conducted across a North Carolina watershed on various land types found that a medium aged pine-mixed hardwood forest had a mean final constant infiltration rate of 12.42 inches per hour. When the forest understory and leaf litter were removed, the resultant lawn had a mean infiltration rate of 4.41 inches per hour (Kays, 1980). Four additional types of disturbed land were tested and had infiltration values around two orders of magnitude less than for the native forest conditions (Kays, 1980).

Improve regional air quality

Trees improve air quality by directly removing pollutants, including nitrogen dioxide, carbon monoxide, sulfur dioxide, ozone, and particulate matter such as dust, ash, pollen, and smoke (MD DNR, 2002; Nowak, 1999). One study estimates the pollutant removal rate is 10 to 14 grams per square meter of canopy per year in eastern cities (Nowak, 1999). Trees also reduce air temperature, which indirectly reduces the emissions of some pollutants that are temperature dependent, such as hydrocarbons released through gasoline evaporation from parked cars (Nowak, 1999; McPherson and others, 1997; Scott and others, 1998). The cooling provided by urban trees can reduce smog levels by up to 6% (Wolf, 1998), and the reduced energy demand in turn reduces the amount of carbon dioxide produced by fossil-fuel power plants. Urban forests in the United States store millions of tons of carbon annually, helping to reduce the level of carbon dioxide in the atmosphere (Rowntree and Nowak, 1991).

One source estimates that a large front yard tree annually absorbs 10 pounds of air pollutants (including 4 pounds of ozone and 3 pounds of particulates), and prevents 330 pounds of carbon dioxide from entering the atmosphere through direct sequestration in the tree’s wood and reduced power plant emissions from energy savings due to cooling (CUFR, 2001). While these numbers may be impressive, stands of trees are even more effective at reducing air pollution than individual trees. Even modest increases of 10% canopy cover in the New York City area were shown to reduce peak ozone levels by 3% of the maximum and by 37% of the amount by which the region exceeded its air quality standard (Casey Trees Endowment Fund, no date). Similar results were found in other eastern cities.

Reduce stream channel erosion

Trees in the riparian zone help to reduce stream channel erosion by stabilizing the soil with their root systems and by adding organic matter. Vegetative cover also prevents erosion by substantially dispersing raindrop energy. Long-term loss of riparian vegetation can result in bank erosion and channel widening, increasing the width/depth ratio of the channel (Hartman and others, 1987; Oliver and Hinckley, 1987; Shields and others, 1994). Trees outside riparian areas indirectly reduce stream channel erosion by attenuating runoff and reducing the total runoff volume that would otherwise contribute to downstream channel erosion.

Improve soil and water quality

Trees improve soil and water quality through uptake of soil nutrients (primarily nitrogen), filtering of sediment and associated pollutants from runoff, and removal of pollutants commonly found in runoff and urban soils (see Box 8 on phytoremediation). Over time, trees also increase the amount of organic matter in the soil, which binds many pollutants. Appendix A summarizes the effect of land cover on water quality in terms of nutrient loads. Sediment loads from forests are estimated at 50 tons of soil per square mile per year, compared with developing areas, which can lose 25,000 to 50,000 tons per square mile per year (Urban Forestry South Expo, no date).

BOX 8. PHYTOREMEDIATION

Phytoremediation is the process of using plants to remove contamination from soil and water. Plants can be used to clean up metals, pesticides, solvents, explosives, crude oil, polycyclic aromatic hydrocarbons, and landfill leachates from contaminated soils (U.S. EPA, 1998). Tree species typically used for phytoremediation include willow, poplar (cottonwood hybrids), and mulberry, because they have deep root systems and are able to control migration of pollutants by consuming large amounts of water (Puckette, 2001; Metro, 2002). Forested buffer strips are one common example of phytoremediation technology that is applied in agricultural settings to filter out pollutants from agricultural runoff before it reaches a stream. Forested buffer strips can also be applied in urban settings, although pollutant removal rates are not as well documented (Schueler, 1995).

Pollutant removal rates for phytoremediation technologies vary greatly, but one study estimated that one sugar maple growing along a roadway removed 60 mg of cadmium, 140 mg of chromium, 820 mg of nickel, and 5,200 mg of lead from the environment during a single growing season (Coder, 1996). More information about phytoremediation can be found in U.S. EPA (1999).

Provide habitat for terrestrial and aquatic wildlife

Forests serve as wildlife habitat that supplies food, water, and cover for a variety of birds, mammals, amphibians, reptiles, and invertebrates. Large areas of contiguous forest are important habitat for interior dwelling species, while narrow strips of forest may connect larger forest tracts. Large forest areas and narrow strips both can serve as migratory corridors for wildlife.

Riparian forests provide multiple benefits for aquatic life. Trees provide leaf litter and large woody debris, which create habitat for fish, macroinvertebrates, amphibians, and reptiles. Leaf litter is also an important source of energy to streams as it is the basis for aquatic community food webs. A typical acre of mature forest will drop between 2 and 3 tons of leaves, twigs, and branches every fall (Envirocast, 2003). When these leaves blow into a stream, they form “packs” that are gradually broken down by fungi and bacteria, dependent on temperature and current velocity (Envirocast, 2003). The fungi are a major food source for insects such as caddisflies and stoneflies, which in turn are a food source for small fish and other aquatic life (Envirocast, 2003).

In urban watersheds, much of the organic matter inputs to streams are from upland areas such as roadsides, where leaves fall onto curb areas and are washed through the storm drain system to the stream. Therefore, upland forests may be as important as riparian forests in urban watersheds, in terms of organic matter inputs to the stream.

Reduce summer air and water temperatures

Riparian forests regulate surface water temperatures for fish and aquatic insects through the shade they provide along stream channels. Temperature is important because it plays a central role in the rate and timing of biotic and abiotic reactions in streams (FISRWG, 1998). The increased impervious cover and lack of forest cover in urban watersheds can increase summer stream temperatures by 2 to 10 degrees Fahrenheit (Galli, 1991). In some regions, summer stream warming can even shift a cold-water stream to a cool-water or a warm-water stream, and this change can be irreversible (FISRWG, 1998). Trees and forests that shade impervious surfaces can reduce the temperature of storm water runoff. Therefore, urban forests can mitigate the thermal shocks that would otherwise be transmitted to urban streams during storms.

Impacts of Impervious Cover on Watershed Health

Most watersheds in the eastern United States were once primarily forested. Today, many of these forests have been cleared to make way for farmland or urban development. As forests are cleared for development in urbanizing watersheds, they are replaced with paved surfaces such as roads, driveways, parking lots, and sidewalks. These paved surfaces combined with rooftops make up impervious cover. All surfaces in a watershed that are not considered impervious cover are generally lumped under the category "pervious cover," and constitute most of the green space in the watershed (Box 9).

Impervious cover has recently been identified as an excellent indicator of stream quality in small watersheds. CWP (2003) summarized recent research findings and has integrated them into a watershed planning tool known as the Impervious Cover Model (ICM). The ICM predicts that most stream quality indicators decline when watershed impervious cover exceeds 10%, with severe degradation expected beyond 25% (CWP, 2003). The ICM predicts the *average* behavior of a group of indicators over a *range* of impervious cover and should not be used to predict the fate of individual species (e.g, trout, mussels).

The impacts of impervious cover on the health of small streams are reflected in four different indicators: hydrologic, physical, water quality, and biological. Impervious cover fundamentally alters the hydrology of urban watersheds by generating increased storm water runoff and reducing the amount of rainfall that soaks into the ground (Figure 2). Storm drain networks are created to efficiently deliver this runoff away from a development site, which increases downstream flooding and channel erosion, and delivers pollutants entrained in storm water runoff. Pollutants commonly found in urban storm water include sediment, nutrients, bacteria, metals, pesticides, and hydrocarbons. Urban storm water runoff also has thermal impacts on the stream, as the water is heated by impervious surfaces during the warm summer months. These increases in pollutant loads and temperature, combined with increases in flood frequency and peaks, have a detrimental effect on water quality, the stability of small stream channels, and the abundance and diversity of aquatic species living in these streams. More information on the impacts of impervious cover on stream health, the ICM, and specific indicators that measure watershed health can be found in CWP (2003).

The impacts of impervious cover described above can be mitigated by "disconnecting" impervious areas so that they are no longer hydraulically connected to the drainage system as well as by increasing tree canopy over the impervious cover. Disconnection can involve redirecting runoff from rooftops or individual parking lots to storm water treatment practices or vegetated areas and allowing the runoff to infiltrate. In fact, infiltrating storm water on-site is the goal of many storm water treatment practices and low-impact development approaches, particularly those that use vegetative cover and amended soil media and are sited to break up and treat runoff from what would otherwise be large expanses of impervious surface.

While some mitigation of impervious cover impacts is possible, conserving existing forests is still the best defense against the deterioration of watershed health from urbanization impacts. Planting new forests can help to mitigate the effects of prior development.

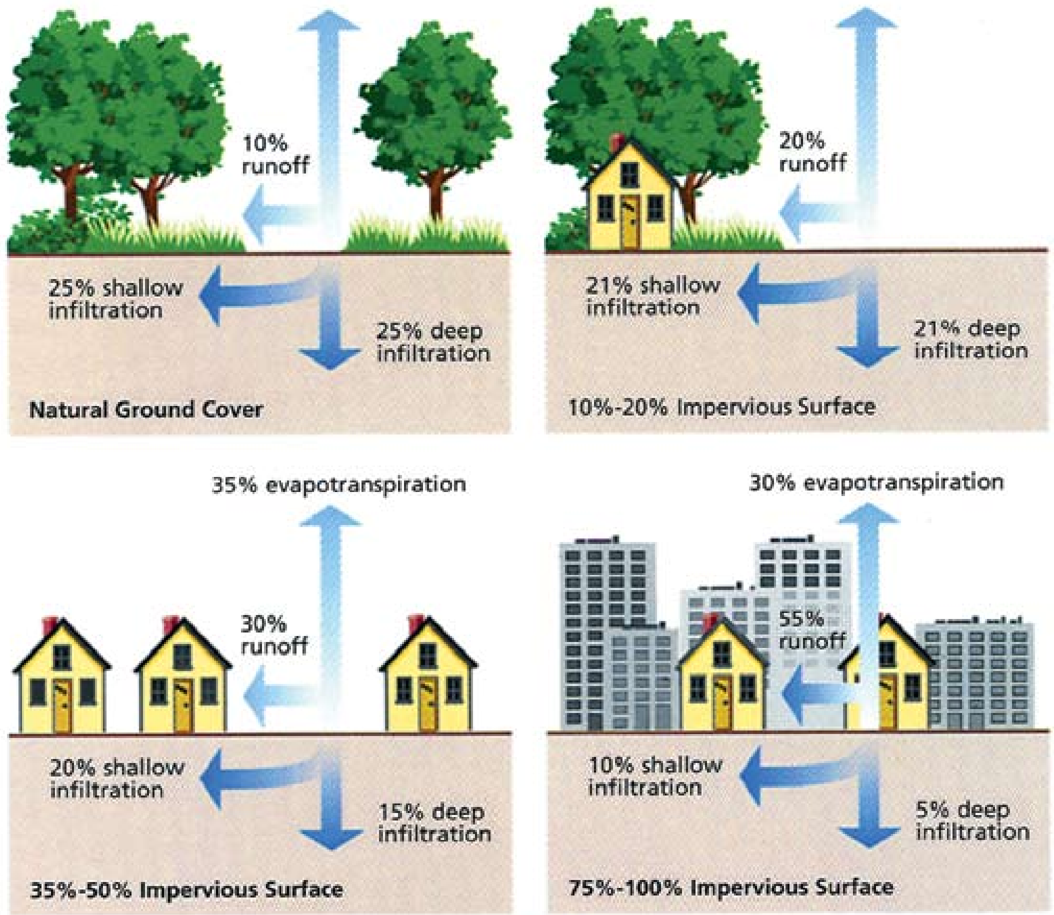


Figure 2. The Impacts of Impervious Cover on the Hydrologic Cycle (Source: FISRWG, 1998, p. 3-21)

BOX 9. ALL PERVIOUS COVER MATTERS

The vegetative cover of urban pervious areas ranges from bare earth to urban forest, but the majority is often turf grass or lawn. Forests are the most beneficial type of pervious cover in terms of watershed health because they reduce storm water runoff by intercepting and storing rainfall. On average, forests produce 30% to 50% less runoff than do grass lawn areas (Pitt and others, 1986), which produce significantly less runoff than impervious surfaces (see Appendix A).

Several studies have found that watershed forest cover may be as important as impervious cover in predicting stream health. One Puget Sound study found that watersheds with at least 65% forest cover usually had a healthy aquatic insect community (Booth, 2000). A Montgomery County, MD, study that used IKONOS imagery to map forest and impervious cover in relation to stream health ratings found similar results (Goetz and others, 2003). For watersheds to have a stream health rating of excellent required at least 65% tree cover in the riparian zone, and a stream health rating of good required at least 45% tree cover overall (Goetz and others, 2003).

Impacts of Urbanization on Forests

As land in a watershed is developed parcel by parcel, formerly continuous forests are divided into smaller patches. This process is referred to as ***forest fragmentation***. As forests are divided into smaller fragments, the proportion of edge to interior habitat increases, creating an "***edge effect***." Edge habitat occurs at the boundaries between different types of land cover, while interior forest habitat is defined as large tracts of continuous forest cover (Jones and others, 1997). Fragmentation diminishes habitat for forest interior dwelling species (e.g., interior-dwelling migratory birds), although the amount of interior forest habitat needed varies for different species (Jones and others, 1997; ELI, 2000). In general, habitat quality declines in relation to the size of the forest fragment.

American Forests estimates that tree cover in urban areas east of the Mississippi has declined by about 30% over the last 20 years, while the footprint of urban areas has increased by 20% (American Forests, no date). In fact, tree canopy cover across the United States averages only 27% in urban areas and 33% in metropolitan areas (Dwyer and Nowak, 2000). As forest cover within a watershed falls below 75%, fragmentation effects, such as changes in species composition and diversity, become more pronounced (U.S. EPA, 1997). The pattern of forest loss is as important as the amount of forest loss. For example, a checkerboard pattern exhibits more fragmentation than a clumped pattern of the same amount of forest (Jones and others, 1997; ELI, 2000). Figure 3 illustrates the loss and fragmentation of forest cover over six decades in the Gwynns Falls watershed in Baltimore County, MD.

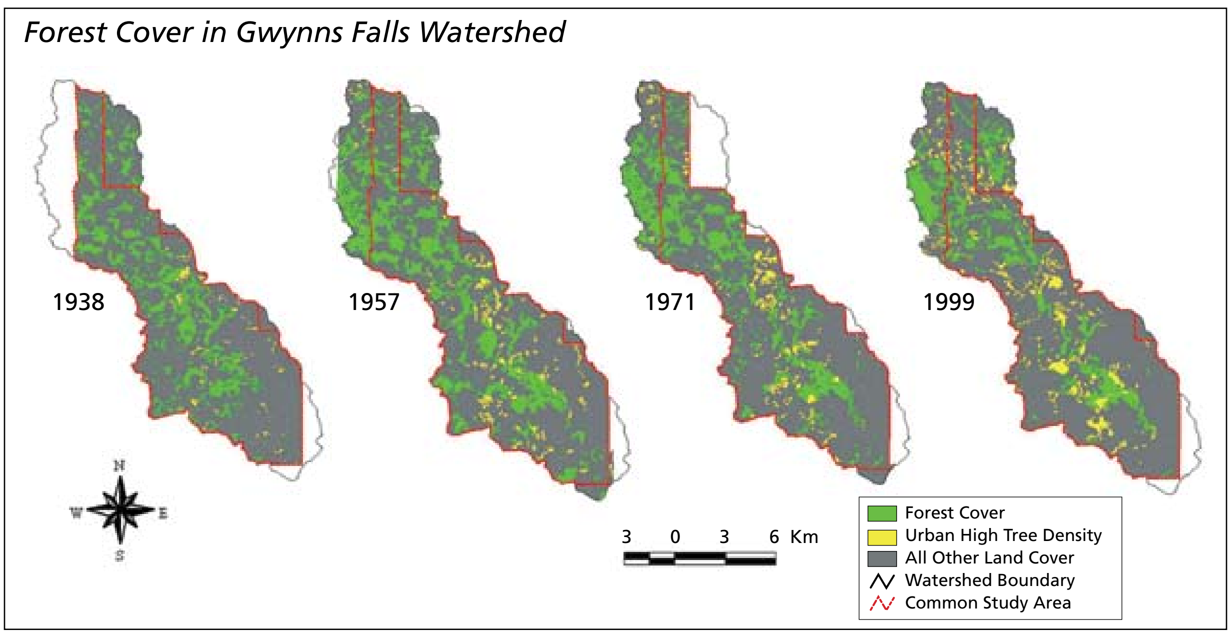


Figure 3. Forest cover was lost in the Gwynns Falls Watershed, Baltimore County, MD, from 1938 to 1999 (Source: Jim Dyer)

Edge effects

Fragmentation can also change the microclimate of the forest, altering species composition and opening the forest to invasive species. The forest interior has very different characteristics from the edge of the forest, and these differences become more pronounced with increased distance between the interior and the edge (Figure 4). The forest interior is more shaded, has higher humidity, and is less exposed to wind than is the forest edge, while the edge has more exposure to light, wind, and rain and contains more sun-loving species (Hanssen, 2003; FISRWG, 1998). The interior and edge habitats may also have different soil characteristics. Wildlife in forest edges are also more vulnerable to external competition, predation, and nest parasitism because they are more accessible to predators (e.g., house cats) and parasites (e.g., cowbirds) (Hanssen, 2003).

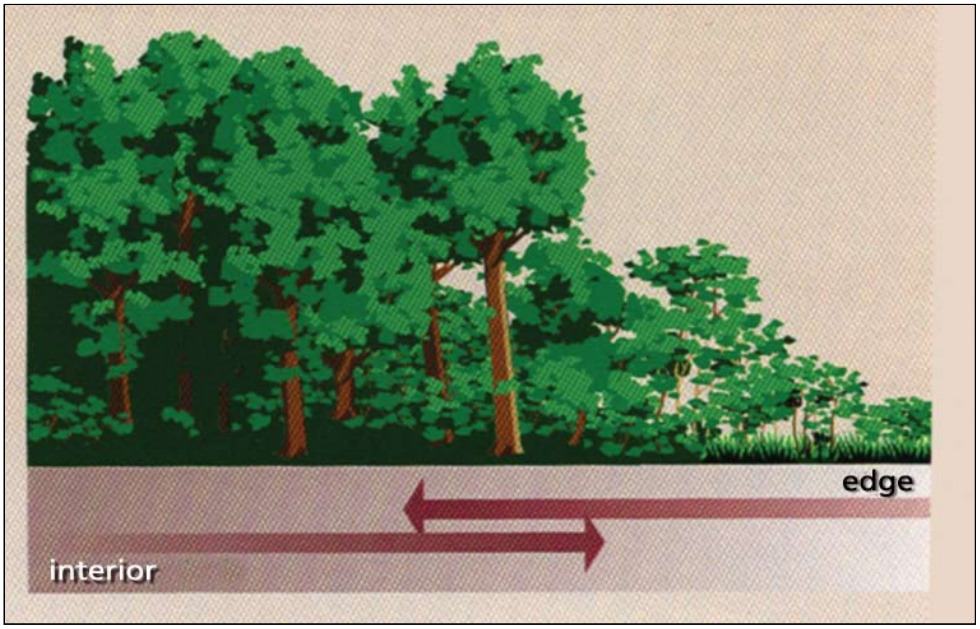


Figure 4. Differences between edge and interior become more pronounced with increased distance (Source: FISRWG, 1998, p. 2-81)

Due to the increased ratio of edge to interior forest habitat in urban watersheds, urban forest remnants are particularly susceptible to invasions of nonnative edge-loving plants such as ailanthus, kudzu, English ivy, and Japanese honeysuckle, and it is not uncommon for these invasive species to become dominant (Figure 5). Herbivory effects from whitetailed deer also tend to increase with increasing edge habitat. Deer browse primarily on woody plants and can thrive in transitional edge habitats that provide plenty of food and ample shelter (MD DNR, 1998). The lack of natural predators in urban areas combined with the effects of fragmentation can also concentrate large populations of deer in small forest fragments by restricting movement, which further magnifies the effects of browsing.

Figure 5. Typical urban forest fragment with invasive species, illegal dumping, and lack of vertical structure

Stresses from nearby development

Remaining urban forest fragments tend to be located in areas that are difficult to develop, such as stream valleys and steep slopes, or in places where trees have been allowed to grow up over time, such as parks and vacant lands. Many stresses are placed on these remaining fragments from nearby development and land use activities. Construction activities can compact root zones and alter drainage patterns around remaining forest patches and groups of trees. Air pollutants such as ozone damage tree foliage and impair photosynthesis, making trees more susceptible to pest outbreaks, disease, and drought (MD DNR, 2002). Urban forests are exposed to higher temperatures than their rural counterparts because of the urban heat island effect, making them more vulnerable to drought. Forest remnants are also stressed by deer overbrowsing and often lack the structure and understory of a healthy forest. Urban forests are also subject to clearing, excessive dumping of trash and rubble, and compaction and erosion from foot traffic and ATVs (Box 10).

BOX 10. TYPICAL CHARACTERISTICS OF URBAN FOREST FRAGMENTS

- Lack of vertical structure
- Populations of invasive plants may dominate
- Fewer native species are present
- Trash and other illegally dumped material is present
- Lack of species diversity (often a monoculture)
- High proportion of edge habitat to interior habitat
- Lack of understory or herbaceous layer
- Poor, compacted soils
- Subject to clearing and encroachment
- Subject to erosion and excessive storm water runoff
- Subject to overbrowsing by deer due to uncontrolled populations
- Large populations of exotic earthworms
- Soil nitrogen present primarily as nitrate.

Changes to riparian areas

Impacts to the riparian forest have their own particular pattern. Urbanization often results in encroachment, tree clearing, and mowing of the vegetated buffer along stream channels. These changes can interrupt the continuity of the stream buffer corridor and undermine its many benefits, such as stream shading and bank stabilization. Urban stream buffers may also be fragmented by road and utility crossings, and are often short circuited by storm water pipes. In commercial settings, buffers are often cleared and replaced with parking lots and riprap directly adjacent to the stream. Homeowners may replace natural buffer cover with turf grass that lacks the root depth needed to maintain bank stability. Finally, stream incision from increased flows in urban streams effectively cuts off the remaining riparian forest from its water source because floodwaters cannot make it up over the banks onto the floodplain.

Unique Properties of the Urban Planting Environment

In addition to the stresses placed on urban trees from surrounding development and land use activities, further difficulties may be caused by past land use activities when attempting to reforest an urban site. Most urban planting sites are highly disturbed, and the most fundamental change is caused by the disturbance of native soils. 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 (Figure 6). Consequently, the soils of urban pervious areas often lack the fertility, tilth, and recharge characteristics of their non-urban counterparts (CWP, 2000a), even if they have not been drastically disturbed.

Figure 6. Native soils disturbed during construction are compacted and contain building rubble

Figure 7. Stripping of topsoil during construction removes most of the nutrients and organic matter vital to plant growth (Source: Derek Booth)

Urban or made soils are typically very compacted, which physically impedes root development and suffocates the tree by limiting available oxygen (VCE, 2002; Coder, 2002). Compacted soils typically become limiting to root growth at soil bulk densities around 1.4 to 1.6 grams/cm^2 or greater (Craul, no date; CWP, 2000a). Compacted soils also have poor drainage, which can cause the tree roots to drown. From a practical standpoint, the hydrology of many urban pervious areas is more similar to impervious areas than to natural ones.

The quality of most urban soils is poor and is usually not ideal for plant growth. Most of the soil organic matter is removed along with the topsoil during construction (Figure 7). Turf is often established after construction, which does not contribute much organic matter to the soil. In addition, the soil pH in urban areas is often elevated from excessive building rubble, which contains calcium.

Soil surveys actually change the classification of the native soil to the ubiquitous moniker “urban soils” after a site is developed because they differ so drastically from the native soil and because they are so highly variable within an individual site that classifying the new soil is not feasible. This extreme variability necessitates some basic sampling and characterization of soil prior to restoration efforts.

Other considerations in the urban planting environment include these: exposure to extreme temperatures from surrounding pavement, conflicts with infrastructure, limited soil volume. More detail on preparing the urban planting environment is provided in Part 3 of this manual series.

Chapter 2: Planning Methods for Increasing Forest Cover in a Watershed

This chapter guides the watershed planner or forester through a six-step method for increasing forest cover in a watershed, defining watershed-based forest cover goals, and identifying priority sites for protection, restoration, and reforestation. Figure 8 presents the six-step method for increasing watershed forest cover, which is explained in detail in this chapter. These methods are only one component of the larger urban watershed restoration process, and should be coordinated with other restoration practices such as those outlined in Schueler (2004). For example, the baseline and sentinel monitoring of watershed conditions recommended in Schueler (2004) are essential to evaluate the effect of increasing forest cover through urban watershed forestry techniques.

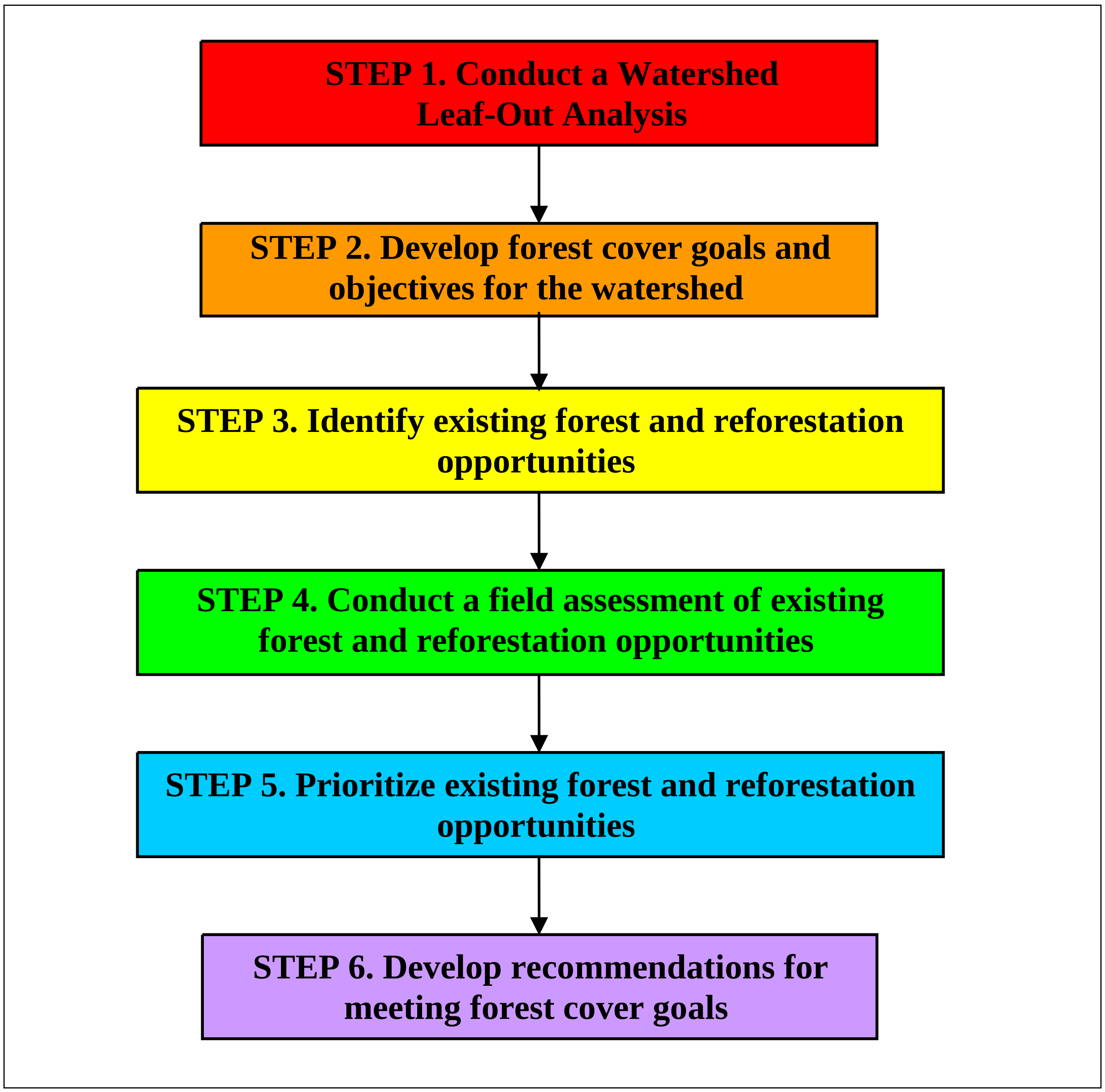


Figure 8. Six-step process for increasing forest cover in a watershed

This method is based on the assumption that a municipal or community program has mapping and other resources and the ability to conduct the method. The method is typically conducted across an entire watershed or subwatershed, but could easily be applied to a different scale, such as a small urban catchment or an entire metropolitan area. In addition, the actual implementation of several of the steps occurs at the individual parcel scale (e.g., evaluating reforestation sites, implementing reforestation projects). The use of Geographic Information Systems (GIS) is required, and the resolution of data should be appropriate for the scale of analysis.

The six-step method described here focuses on *planning* to increase forest cover in the watershed. Detailed guidance on *implementation* of techniques to increase forest cover is outside the scope of this manual; however, specific references direct the reader to the best implementation resources.

Step 1: Conduct a Watershed "Leaf-Out" Analysis

Watersheds are constantly gaining and losing forest cover at the same time due to the clearing of forests for land development, homeowner landscaping, abandonment of farm land or open space, reforestation, or other activities. The first step in planning to increase forest cover entails an inventory of existing and future watershed land cover to systematically account for forest losses and gains. The inventory method described here is referred to as the "Leaf-Out" Analysis because it is similar to a build-out analysis, which predicts future impervious cover with development based on zoning categories. The Leaf-Out Analysis focuses on future forest cover rather than on impervious cover. This analysis can be used to identify and evaluate the location, distribution, average size, future use, and ownership of forest fragments and reforestation sites. This information can then be used to determine which types of projects (protection, restoration, or reforestation) and what types of lands (public, private, residential turf, parks) will yield the greatest return in terms of increasing forest cover in the watershed. This step requires the use of GIS (see Box 11).

These substeps of the Leaf-Out Analysis are described in detail below:

Step 1.1	Estimate the Distribution of Current Land Cover in the Watershed
Step 1.2	Identify Protected and Unprotected Lands in the Watershed
Step 1.3	Determine Whether Parcels are Developed or Undeveloped
Step 1.4	Determine Allowable Zoning on Undeveloped Land
Step 1.5	Summarize Watershed Data
Step 1.6	Acquire Forest Cover Coefficients
Step 1.7	Estimate Future Forest Cover in the Watershed.

BOX 11. USING GEOGRAPHIC INFORMATION SYSTEMS FOR THE LEAF-OUT ANALYSIS

A Geographic Information System (GIS) is a computer-based tool for mapping and analyzing all sorts of geographically referenced (spatial) data. GIS is a common tool by which local governments manage property data, map natural resources, plan future transportation corridors, and provide efficient emergency response. Maintaining a GIS can require extensive resources for data collection, staff training, hardware and software acquisition, and more.

The inventory of current and future land cover described in this section requires the use of GIS; therefore, some basic understanding of GIS is helpful to navigate this section. Since a wide variety of GIS software is available, the steps described in this section refer only to general procedures rather than software-specific manipulations. The data layers created in this analysis have applicability and utility across a wide variety of local departments and analyses. Following are the minimum GIS layers required for the inventory of land cover in a watershed.

- Watershed and subwatershed boundaries (delineation methods available at the Storm Water Manager's Resource Center: www.storm watercenter.net)
- Open water and wetlands
- Topography
- Land cover (e.g, impervious, forest, turf)
- Protected lands (e.g., conservation easements)
- Parcel boundaries
- Land use (e.g., schools, parks)
- Zoning
- Natural resources (e.g., stream buffers, steep slopes, floodplains)
- Monitoring data (e.g., water quality, habitat, biological)
- Cultural, recreational, or historical sites
- Storm water treatment practices and other drainage features.

Many of these layers are available for free download from State Web sites such as in Maryland, the State Geographic Committee's Technology Toolbox: www.msgic.state.md.us. De la Cretaz, and others (2003) provide guidance on compiling and analyzing watershed GIS data, and Appendix B provides a list of additional data resources.

Step 1.1 Estimate the Distribution of Current Land Cover in the Watershed

The first step is to create or acquire a GIS layer of current land cover in the watershed that distinguishes between three cover types: impervious cover, forest cover, and nonforest vegetative cover. Open water and non-forested wetlands are not included in the land cover analysis.

- *Impervious cover* is defined as any surface that does not allow water to infiltrate and typically includes roads, buildings, parking lots, driveways, sidewalks, and decks.

- *Forest cover* includes all land that is primarily covered by trees and shrubs, although the actual classification of forest cover can vary greatly with the data source (see Box 1 on page 2). The ideal forest cover layer in this scenario is actually urban tree canopy, which includes the canopy of individual trees, groups of trees, and forests.

- *Non-forest vegetative cover* can include turf, bare ground, landscaping, meadow, and crops. In urban watersheds, the majority of non-forest vegetation is usually turf. Since it is difficult to distinguish between these cover types from aerial photos, and because all of these cover types are potential reforestation candidates, any land cover that is not forest or impervious is considered turf for the purposes of this analysis.

Depending on current GIS data, staff expertise, and resources available, there are three options for obtaining a current land cover layer:

1. Use existing local or regional land cover GIS layers (see Appendix B for potential sources).
2. Derive land cover from high-resolution imagery using GIS and remote sensing techniques.
3. Use GIS to digitize land cover from recent aerial photos.

If recent land cover maps of an appropriate scale and resolution are not available, one option is to acquire high-resolution satellite or aerial imagery and use remote sensing software to interpret and classify the images into the three land cover categories. Existing imagery that may be used includes USGS digital orthoquads and IKONOS satellite imagery. Minimum standards for measuring urban tree canopy include a resolution of 1 meter and imagery that is no more than 3 years old (CBP, 2004). Two techniques that utilize image classification to derive forest cover are American Forests CITYgreen (www.americanforests.org) and the Baltimore Strategic Urban Forests Assessment (Irani and Galvin, 2002).

In the CITYgreen analysis, high resolution satellite and aerial imagery is used to create a tree canopy layer for input into the CITYgreen software. American Forests has developed a method of classifying the imagery to create this 'green data' layer. This layer is used to calculate the benefits of the canopy in terms of runoff reduction, air quality, carbon storage and energy savings. For more information about CITYgreen, see www.americanforests.org.

The Baltimore Strategic Urban Forests Assessment (SUFA) was modified from the Maryland Strategic Forest Land Assessment (SFLA) (MD DNR, 2003) for application to an urban area. The SUFA method involved acquiring high resolution satellite imagery of the study area and using remote sensing software and techniques to interpret the image by creating "masks" of the tree canopy cover, non-tree vegetation, and impervious surfaces within the jurisdiction. These masks were then overlaid with local land use, zoning, and resource management data to create an "opportunity mask" of potential planting sites prioritized based on local need. For a detailed description of the methods used, see Irani and Galvin (2002) or the SFLA Web site at www.dnr.state.md.us/forests/download/sfla_report.pdf.

A third option for deriving land cover is to acquire aerial photos and directly digitize land cover layers from these photos (see Appendix B for sources of aerial photos). This method can be time-consuming but may be more affordable than using satellite imagery, particularly if some of the land cover layers already exist in GIS format.

Once the GIS layer of current land cover has been acquired or developed, the area of each cover type in the watershed should be quantified (Figure 9, Step 1.1).

Step 1.2 Identify Protected and Unprotected Lands in the Watershed

The next step is to create or acquire a GIS layer of protected and unprotected lands, in both public and private ownership. Protected lands are defined as land protected from future development through the application of conservation easements or by local regulations that protect specific natural resources. The types of protected land vary in each watershed, but may include wetlands, floodplains, stream corridors or buffers, steep slopes, hydric or erodible soils, parkland, land in conservation easements, karst features, and historic or cultural sites. Protected lands can be digitized from paper maps or from aerial photos if they do not currently exist in GIS format. The final GIS layer should indicate which lands are protected. All remaining lands are designated as unprotected (Figure 9, Step 1.2).

Step 1.3 Determine Whether Parcels Are Developed or Undeveloped

The next step is to create or acquire a GIS layer of developed and undeveloped parcels in the watershed to identify which parcels have already been developed, or “built-out” to the maximum extent allowed by zoning (Figure 9, Step 1.3). The development status (developed or undeveloped) of a parcel may be readily available in the associated data table of a good parcel boundary GIS layer. Ideally, this layer will contain ownership data to be used later to prioritize sites based on ownership and to contact landowners about potential projects. If this is not the case, the development status of each parcel can be estimated by initially classifying all parcels containing buildings as developed. Aerial photos and local knowledge of the area can be used to verify this classification. Parcel boundaries can be digitized from paper maps if they do not currently exist in GIS format.

Alternatively, state planning agencies or the municipal department that handles land development permits may have a composite set of parcel maps in a digital format or a database of developed and undeveloped parcels (e.g., property tax maps) that can be linked to a GIS layer. One example is the Maryland PropertyView Database available from the State Planning Department: www.mdp.state.md.us/data/index.htm.

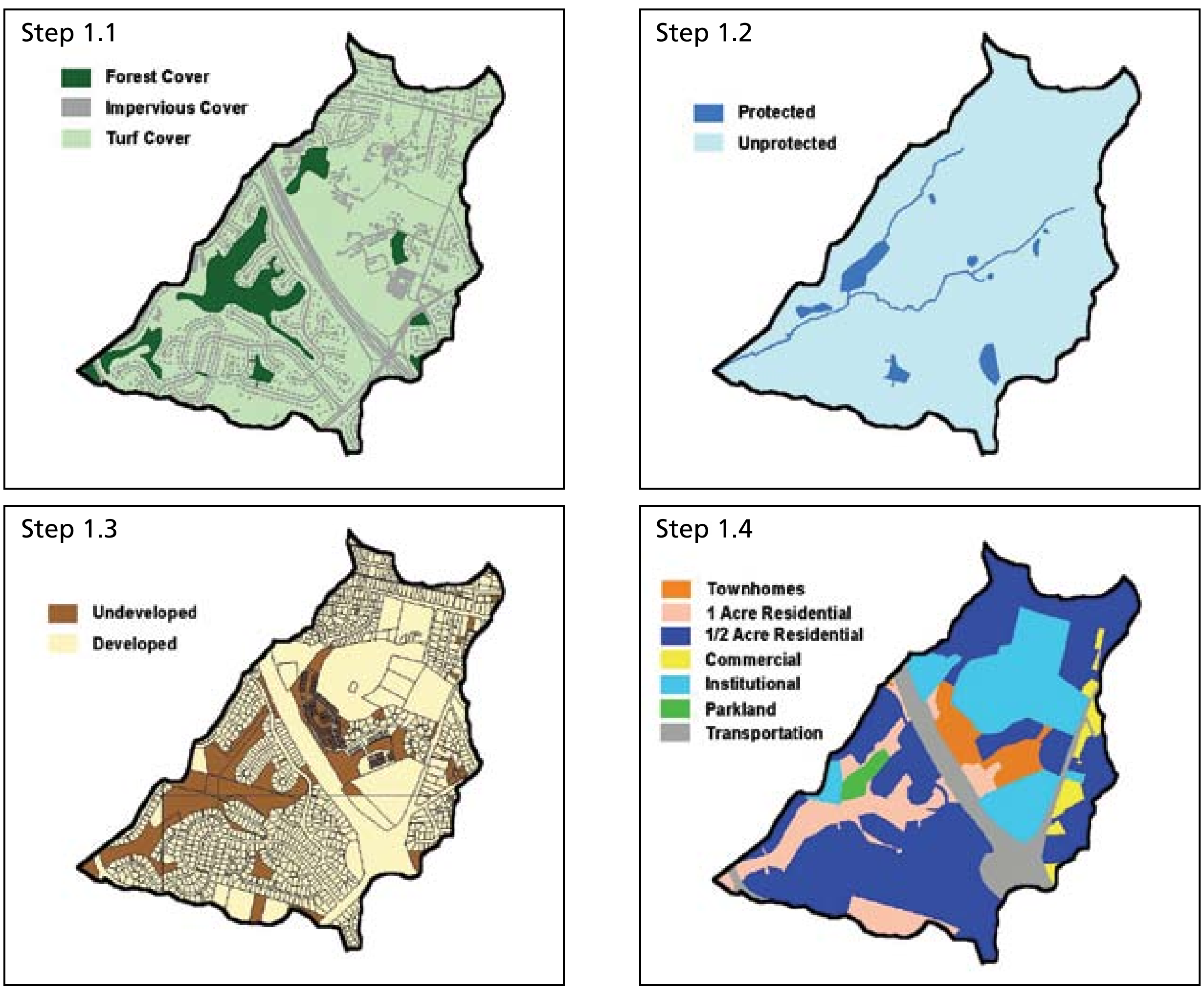


Figure 9. Example maps created as a result of the Leaf-Out Analysis: Step 1.1 – current land cover (upper left), Step 1.2 – protected lands (upper right), Step 1.3 – development status (lower left), and Step 1.4 – zoning (lower right).

Step 1.4 Determine Allowable Zoning on Undeveloped Land

Most local planning and zoning departments maintain a GIS or paper map of zoning categories, or both. A zoning map dictates the allowable land uses and development densities within the community and provides a snapshot of what land use will look like with future build-out. If a GIS layer of zoning does not exist, one can be digitized from the paper zoning map. If the watershed spans more than one community, zoning information from each community must be acquired and combined (Figure 9, Step 1.4).

Step 1.5 Summarize Watershed Data

In this step, the data collected in the four previous steps is used to develop a summary table that provides the necessary variables for estimating future forest cover (Table 4). This can be done using GIS by merging the four layers created in Steps 1.1 through 1.4 and querying the resulting data table. The variables highlighted in Table 4 are inserted into a worksheet designed to estimate future forest cover in Step 1.7.

Table 4. Summary of Watershed Data

Zoning Category	Current Impervious Cover (acres)	Current Forest Cover (acres)		Current Turf Cover (acres)		
				Developed		
		Protected/ Developed	Buildable (unprotected/ undeveloped)	Public	Private	Undeveloped
Agriculture	100	1,000	50	0	3,000	50
Open urban land	150	2,000	100	4,000	0	0
2 acre residential	500	500	200	0	4,000	1,000
1 acre residential	1,000	500	2,000	0	2,000	500
½ acre residential	1,000	500	3,000	0	1,500	1,000
¼ acre residential	2,000	500	1,000	0	1,000	500
⅛ acre residential	2,000	0	50	0	150	100
Townhomes	4,000	0	500	0	100	400
Multifamily	3,000	0	100	0	100	0
Institutional	1,000	0	500	3,000	500	0
Light industrial	5,000	0	500	0	50	100
Commercial	5,000	0	2,000	0	500	500
Total	24,750	5,000	10,000	7,000	2,950	4,150

Each of the variables quantified in this step serves some function in estimating future forest cover:

- The *total amount of current impervious cover* in the watershed will limit the potential for future forest cover (unless impervious cover is removed in order to reforest).
- *Forested land that is already either protected or developed* is assumed to remain forested with future watershed development.
- *Forested land that is both unprotected and undeveloped* is considered "buildable," and some proportion of that forest will be cleared during future development (Step 1.6 will estimate that proportion).
- *Developed turf* probably provides the best opportunities for reforestation, especially public land; however, only some proportion of public turf will actually be available for reforestation. Privately owned developed turf is likely to be residential lawns or commercial or industrial land and has the potential to greatly increase forest cover by reforestation, but will require extensive education, outreach, and possibly incentives to be implemented.

- *Undeveloped turf* may also provide some opportunity for reforestation; however, land should always be reforested in conjunction with protection measures, to ensure long-term sustainability of the forest.

Step 1.6 Acquire Forest Cover Coefficients

Forest cover coefficients represent the fraction of developed land that is forest. These coefficients are applied to specific zoning categories to estimate the amount of future forest cover on all buildable land in the watershed. Little data exist for forest cover or turf cover coefficients; however, some data is available that represent the fraction of developed land that is impervious. The methods used to derive these impervious cover coefficients may be used to estimate forest cover and turf cover coefficients.

Impervious cover coefficients for 12 urban and suburban land uses are available from Cappiella and Brown (2001) and are presented in Table 5. These coefficients were derived from recently developed urban-suburban areas in the Chesapeake Bay region and are applicable to areas with similar types of development. Where possible, local or regional estimates of impervious cover should be used. If none are available, communities should derive their own from local data (see Cappiella and Brown, 2001, for methods). Communities should also derive their own forest and turf cover coefficients by analyzing limits of disturbance on site plans or by analyzing turf cover or forest cover at the parcel scale as a sample of actual development sites. Appendix C and Cappiella and Brown (2001) provide detailed methods for deriving land cover coefficients.

Impervious, forest, and turf cover percentages are also provided in Table 5 for three forest conservation scenarios. These percentages are examples only and are based on a number of assumptions and data sources described below. Conversion of these percentages to coefficients for use in worksheets requires division by 100. Additional data sources that may be used to develop land cover coefficients are provided in Appendix D.

Table 5. Example Land Cover Percentages for Three Forest Conservation Scenarios[1]

Zoning Category	Impervious Cover (%)[2]	Turf Cover (%)[3]			Forest Cover (%)[3]		
		NFC	IFC	DFC	NFC	IFC	DFC
Agriculture	2	93	83	78	5	15	20
Open urban land	9	86	76	41	5	15	50
2 acre residential	11	84	74	39	5	15	50
1 acre residential	14	81	71	36	5	15	50
½ acre residential	21	74	64	54	5	15	25
¼ acre residential	28	67	57	47	5	15	25
⅛ acre residential	33	62	52	47	5	15	20
Townhomes	41	54	44	39	5	15	20
Multifamily	44	51	41	36	5	15	20
Institutional	34	61	51	46	5	15	20
Light industrial	53	42	32	32	5	15	15
Commercial	72	23	13	13	5	15	15

[1]Forest Conservation Scenarios:
NFC — No Forest Conservation = clearing can proceed anywhere at the site except protected wetlands.
IFC — Indirect Forest Conservation = some site areas cannot be cleared because of steep slopes, wetland buffers, stream buffers, floodplains, or other local clearing restrictions.
DFC — Direct Forest Conservation = additional site areas cannot be cleared because of explicit forest conservation or afforestation requirements at the site (e.g., Maryland Forest Conservation Law).
[2]Impervious cover percentages are from Cappiella and Brown (2001).
[3]Turf cover and forest cover percentages are example values only.

The turf and forest cover percentages presented in Table 5 are representative of three tiers of local forest conservation regulations: no forest conservation, indirect forest conservation, and direct forest conservation.

The *No Forest Conservation (NFC)* scenario applies to communities that have no forest conservation or other natural resource conservation regulations that apply during land development. Under NFC, the entire site can be graded, except for state or federally delineated wetlands. For the forest cover percentages presented in Table 5, the assumption was made that a minor fraction of forest cover (5%) may be retained during construction.

The *Indirect Forest Conservation (IFC)* scenario applies to communities that have some additional regulations that prevent clearing on portions of a development site containing stream buffers, steep slopes, floodplains, or other sensitive natural area. These areas often contain forest fragments, and therefore indirectly contribute to forest conservation, although they may represent a very small fraction of the site. The amount of forest conserved will vary depending on how much of the site is currently forested and located within areas such as floodplains, steep slopes, and stream buffers. For the forest cover percentages presented in Table 5, the assumption was made that approximately 15% of any given site would be preserved as forest.

The *Direct Forest Conservation (DFC)* scenario applies to communities with defined forest conservation or afforestation requirements at the development site, in addition to the environmental criteria listed under the indirect forest conservation scenario. The forest cover percentages presented in Table 5 were primarily based on the Maryland Forest Conservation Act criteria, which require a certain percentage of a development site to be preserved as forest or reforested during development.

The turf cover percentages presented in Table 5 reflect the remaining land after impervious cover and forest cover are subtracted from the total land area.

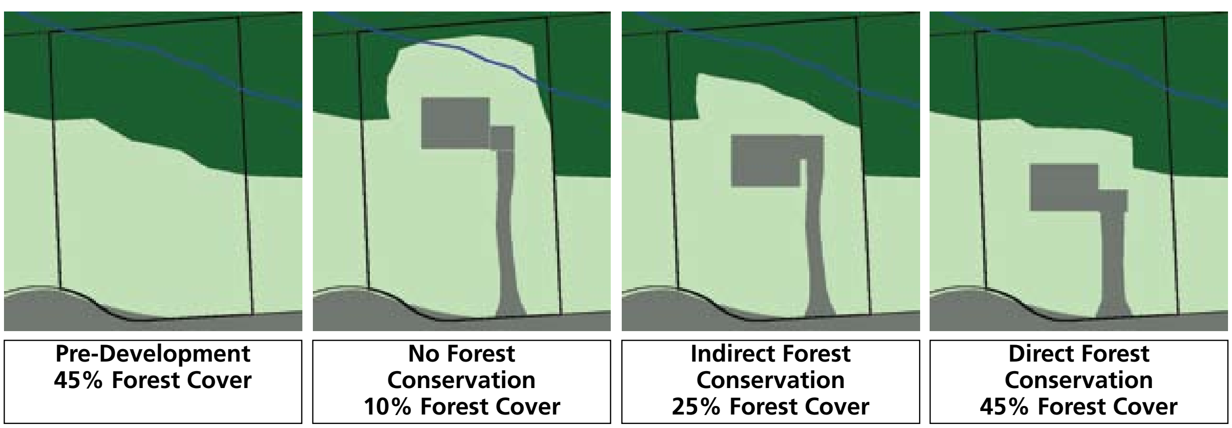


Figure 10. Effect of forest conservation regulations at the development site

Figure 10 illustrates the three tiers of forest conservation regulations. Prior to development, the parcel shown in Figure 10 had 45% forest cover (dark green). With development under the NFC scenario, only a small portion of forest on the site was preserved, with a net forest cover of 10%. Under the IFC scenario, a stream buffer ordinance that restricts disturbance of native vegetation within 100 feet of all streams resulted in the developer conserving additional forest along the stream that runs through the property. The net forest cover for this scenario was 25%. Under the DFC scenario, a forest conservation ordinance that required preservation of 40% of the site as forest resulted in a net forest cover of 40% and total forest loss of only 5%.

Most communities fall into one of these three tiers of forest conservation. Communities should select the appropriate forest cover coefficients depending on their prevailing regulations. As illustrated in Table 5, land cover coefficients vary with the zoning category and the forest conservation scenario; however, one variable not reflected in this table is the prior land use of the site. Land in agricultural use will have less forest cover to start with compared with a forested parcel and so will likely have lower forest cover coefficients. In addition, forest cover coefficients that are derived for older developments may tend to be higher than for more recently developed areas because trees have been planted or allowed to grow up over time in older developments. This variability and the current lack of data on forest and turf cover coefficients points to the derivation of land cover coefficients as a major data gap in this analysis and an area for future research.

Forest cover coefficients will be used in Step 1.7 to estimate future forest cover on buildable lands in the watershed. The percentages shown in Table 5 can be converted to default coefficients by dividing them by 100. Data provided in Appendix D may also be used until detailed studies are conducted to derive more precise information.

Step 1.7 Estimate Future Forest Cover in a Watershed

The final step in the Leaf-Out Analysis is to estimate future forest cover in the watershed under full build-out conditions. This initial estimate of future forest cover is intended to quantify forest cover under a worst-case or “do-nothing” approach and does not account for any future or planned forest conservation or reforestation efforts or regulations. Step 2, Develop Forest Cover Goals and Objectives, models the effect of various forest protection and reforestation techniques on future forest cover.

Box 12 summarizes the assumptions used in estimating future forest cover. These assumptions should be modified when more detail is available regarding future development patterns in a particular watershed. The Leaf-Out Analysis worksheet can be used to estimate future forest cover in the watershed under a worst-case scenario (no additional reforestation or conservation efforts). An example is shown in Box 13, and a blank worksheet is provided in Appendix E. Data summarized in Table 4 on page 24 (Step 1.5) and forest cover coefficients derived from local information (in Step 1.6) should be used to fill in the blanks in the worksheet.

BOX 12. ASSUMPTIONS USED IN ESTIMATING FUTURE FOREST COVER IN A WATERSHED

1. All developed land will remain in its current land cover.
2. All protected land will remain in its current land cover.
3. All impervious cover will remain impervious (e.g., no removal of pavement).
4. All land that is unprotected and undeveloped is considered “buildable” and is subject to future development under allowable zoning.
5. Full buildout of the watershed will occur based on allowable zoning (e.g., no re-zoning).
6. Future land cover of all buildable land can be estimated by applying the appropriate land cover coefficients for each zoning category.
7. The land cover coefficients chosen should reflect the current status of forest conservation regulations in the watershed.

BOX 13. LEAF-OUT ANALYSIS WORKSHEET FOR ESTIMATING FUTURE FOREST COVER IN A WATERSHED--WORST-CASE SCENARIO (e.g., no additional reforestation or conservation efforts)

Section 1. Future Forest Cover

Current Protected or Developed Forest Cover:	*5,000*	acres
From Table 4. All protected or developed forest will remain forested.	+	
Priority Forest Area Protected	*0*	acres
See section 2 of this worksheet. Default value is zero.	+	
Area of Forest Conserved During Development	*2,780*	acres
See section 2 of this worksheet.	+	
Area Reforested	*0*	acres
Default value is zero.	=	
Total Future Forest Cover	*7,780*	acres

Section 2. Forest Conserved During Development

Zoning Category	Buildable Forest (acres)		Priority Forest Protected (acres)		Buildable Forest Remaining (acres)		Forest* Cover Coefficient		Forest Conserved During Development (acres)
Agriculture	50	-	0	=	50	x	.50	=	25
Open urban land	100	-	0	=	100	x	.50	=	50
2 acre residential	200	-	0	=	200	x	.50	=	100
1 acre residential	2,000	-	0	=	2,000	x	.50	=	1,000
½ acre residential	3,000	-	0	=	3,000	x	.25	=	750
¼ acre residential	1,000	-	0	=	1,000	x	.25	=	250
⅛ acre residential	50	-	0	=	50	x	.20	=	10
Townhomes	500	-	0	=	500	x	.20	=	100
Multifamily	100	-	0	=	100	x	.20	=	20
Institutional	500	-	0	=	500	x	.20	=	100
Light industrial	500	-	0	=	500	x	.15	=	75
Commercial	2000	-	0	=	2,000	x	.15	=	300
Total	10,000		0						2,780

* Use forest cover coefficients that represent forest conservation requirements in your area

Section 3. Results Summary

Total Current Forest Cover	*15,000*	acres		
From Table 4.	-			
Total Future Forest Cover	*7,780*	acres		
From Section 1 above.	=			
Future Forest Loss	*7,220*	acres	*48*	%

The worksheet result gives an estimate of future forest loss (%) in the watershed with no additional forest conservation or reforestation efforts. In the example shown, 48% of existing forest in the watershed is lost to development.

The USDA Forest Service's Northeastern Research Station is developing a new tool to project future forest canopy cover that may facilitate the Leaf-Out Analysis. The tool involves a GIS-integrated management decision program that is a component of the Urban Forest Effects (UFORE) Model. This tool is called UFORE Future Effects and is designed to project future canopy cover over a 30-year period based on estimated growth and mortality rates. More information about UFORE is available at www.fs.fed.us/ne/syracuse/Tools/UFORE.htm and www.ufore.org/.

Step 2: Develop Forest Cover Goals and Objectives for the Watershed

The second step is to develop overall goals for increasing forest cover in both the watershed and the community, and to identify specific objectives for attaining these goals. Forest cover goals should be specific, measurable, and realistic, and have an associated timeline for attainment.

Step 2.1 Set Numerical Targets for Forest Cover

A numerical target for forest cover should be defined first for the entire community, and then for each individual watershed within the community. American Forests recommends 40% cover for most metropolitan areas, and a number of communities have already adopted this as a goal (see Appendix F). Across the United States, tree canopy cover currently falls below this standard, averaging 27% in urban areas and 33% in metropolitan areas (Dwyer and Nowak, 2000).

A recent Chesapeake Bay Program directive encourages communities to adopt canopy goals (Box 14) and recommends that goals should represent an increase in overall tree cover, be set for a 10-year horizon, and establish targets for percent increase in forest cover at specified intervals (CBP, 2004). Goals should also take into account current forest cover, current and planned development patterns and regulations, and resources available for reforestation and protection efforts. The Urban Forest Effects (UFORE) Web site provides data on current canopy cover for 21 U.S. cities that may be used as a starting point for developing community forest cover targets: www.fs.fed.us/ne/syracuse/Data/data/htm.

BOX 14. CHESAPEAKE BAY PROGRAM URBAN CANOPY GOALS

In 2003, the Chesapeake Executive Council signed Directive #04-01 expanding the Chesapeake Bay Program goals for riparian forest buffers. The Directive clearly recognized the importance of maintaining and increasing urban tree canopy as a way to extend the watershed functions of the forest in these developed areas. Furthermore, the directive established two specific urban tree canopy goals:

- By 2010, work with at least five local jurisdictions and communities in each state to complete an assessment of urban forests, adopt a local goal to increase urban tree canopy and encourage measures to extend forest buffer functions in urban areas.

- Encourage increases in the amount of tree canopy in all urban and suburban areas by promoting the adopting of tree canopy goals as a tool for communities in watershed planning.

Because most metropolitan areas contain multiple watersheds that often have varying land use and development patterns, a numerical target should be defined for each watershed, based on community-wide targets but taking into account specific watershed protection or restoration goals and using the results of the Leaf-Out Analysis. It may not be realistic for some watersheds to meet the community-wide forest cover goal, while other watersheds may surpass them. To date, few communities have adopted numerical targets for forest cover at the watershed scale; however, some data indicate that watershed forest cover of at least 45% to 65% is most beneficial in terms of stream health (Appendix F). These studies provide a starting point for setting watershed-wide forest cover goals. Table 6 provides some example forest cover goals for four watershed scenarios.

Table 6. Example Forest Cover Goals for Four Watershed Scenarios

Watershed Type	Impervious Cover %	Forest Cover Goal	Benefits of Forest Cover
Suburban-Forested	< 25	60% minimum with 70% riparian forest cover	• Maintain aquatic ecosystem • Improve filtering capacity • Wildlife habitat • Stream protection
Suburban-Agricultural	< 25	40-50% minimum	• Maintain aquatic ecosystem • Improve filtering capacity • Wildlife habitat • Stream protection
Urban-Suburban	26 to 60	25-40% minimum	• Storm water runoff reduction • Reduce urban heat island • Wildlife habitat • Increase esthetic value • Provide recreational opportunities
Urban	> 60	15-25% minimum	• Reduce urban heat island • Storm water runoff reduction • Public health and air quality • Community livability

The forest cover goals presented in Table 6 are examples only and should be refined based on individual watershed characteristics, modeling, or literature review, to directly address storm water, air quality, or other outcomes. Current forest cover should be used as a starting point for goal setting. Current watershed impervious cover may also help determine the maximum limit of forest cover that it is possible to achieve without removal of impervious surfaces. Numerical forest cover targets should be revisited periodically and revised if necessary. Cost estimates for implementing forest conservation and reforestation objectives are necessary for communities to determine what is a realistic forest cover increase to achieve given a specific timeframe and budget. Two examples are presented in Box 15.

BOX 15. QUANTIFYING REALISTIC FOREST COVER GOALS

A study of the urban forest in Syracuse, NY, found that the current forest cover in the city was 26.6% for the 25.1 square mile area. A specific recommendation was made in the city's Urban Forest Management Plan to increase overall canopy cover to 30%. Assuming that existing forest cover was maintained, this **increase of 3.4%** could be implemented over **25 years** by planting 1,360 new trees each year (Nowak and O'Connor, 2001). Annual costs for implementation are estimated at $272,000 (based on cost of $200 per tree for planting and maintenance from Connecticut Climate Change, 2004).

A similar study by the North East State Foresters Association (Luley and Bond, 2002) used a model to determine that a 1**0% increase in canopy cover** was realistic for the New York City metropolitan region (an area of 1,950 square miles) to achieve over a **30-year time period.** This increase would bring the total tree canopy cover up to 41%. To achieve this goal, more than 1 million trees would need to be planted each year at an annual cost of $212 million (using the above cost estimate).

Step 2.2 Define Priority Objectives to Meet Goals

Forest cover goals for a watershed should represent an increase in the existing percentage of forest cover. The specific objectives utilized to meet forest cover goals may vary with each watershed and should be based on the data derived from the Leaf-Out Analysis (e.g., current impervious cover, area of protected forest, area of buildable forest, proportion of public and private developed turf).
Table 7 provides guidance on identifying priority objectives to meet forest cover goals in specific types of watersheds.

Table 7. Linking the Leaf-Out Analysis With Forest Cover Goals and Priority Objectives

Urban Watershed Forestry Objective	Characteristics of Watersheds Where Objective is Prioritized
A. Protect Priority Forests	Significant proportion of buildable forest, significant forest lost to development in Leaf-Out analysis scenario, large tracts of forest owned by single landowners
B. Prevent Forest Loss During Development and Redevelopment	Significant proportion of buildable forest, significant forest lost to development in Leaf-Out analysis scenario, current forest cover regulations do not directly or indirectly protect forests
C. Maintain Existing Forest Canopy	Highly developed watershed with little or no buildable forest remaining, majority of forest is on developed land
D. Enhance Forest Fragments	Significant protected forest exists, little remaining buildable forest
E. Plant Trees During Development and Redevelopment	Significant proportion of buildable land, current conservation regulations do not provide much protection of trees (and is not feasible or acceptable to change), or most of buildable land is turf (prior agricultural land)
F. Reforest Public Land	Significant proportion of public turf
G. Reforest Private Land	Significant proportion of private turf, private turf is held by a few large landowners, or private turf is held by many small landowners but represents the best opportunity for increasing forest cover (e.g., very little forest exists to protect, little buildable forest left, little public turf)

Step 2.3 Evaluate Effect of Objectives on Future Forest Cover

The Leaf-Out Analysis provides a baseline estimate of future land cover under a worst case or "do nothing" scenario. Based on priority forest cover objectives, alternative scenarios can be evaluated to determine their impact on future forest cover. The Leaf-Out Analysis worksheet in Box 16 illustrates an example scenario in which future forest loss was reduced from a 48% loss to a 7% gain in watershed forest cover.

BOX 16. LEAF-OUT ANALYSIS WORKSHEET FOR ESTIMATING FUTURE FOREST COVER IN A WATERSHED (FOREST CONSERVATION AND REFORESTATION SCENARIO)

Section 1. Future Forest Cover

Current Protected or Developed Forest Cover:	***5,000***	acres
From Table 4. Protected or developed forest will remain forested.	+	
Priority Forest Area Protected	***2,000***	acres
See section 2 of this worksheet. Select area to protect as part of an urban watershed forestry program.	+	
Forest Conserved During Development	***5,000***	acres
See section 2 of this worksheet.	+	
Area Reforested	***4,000***	acres
Select area to reforest as part of an urban watershed forestry program.	=	
Total Future Forest Cover	***16,000***	acres

Section 2. Forest Conserved During Development

Zoning Category	Buildable Forest (acres)		Priority Forest Protected (acres)		Buildable Forest Remaining (acres)		Forest* Cover Coefficient		Forest Conserved During Development (acres)
Agriculture	*50*	-	*500*	=	*50*	x	*.50*	=	*25*
Open urban land	*100*	-	*500*	=	*100*	x	*.50*	=	*50*
2 acre residential	*200*	-	*50*	=	*200*	x	*.50*	=	*100*
1 acre residential	*2,000*	-	*250*	=	*2,000*	x	*.50*	=	*1,000*
½ acre residential	*3,000*	-	*0*	=	*3,000*	x	*.50*	=	*1,500*
¼ acre residential	*1,000*	-	*0*	=	*1,000*	x	*.50*	=	*500*
½ acre residential	*50*	-	*0*	=	*50*	x	*.50*	=	*25*
Townhomes	*500*	-	*0*	=	*500*	x	*.50*	=	*250*
Multifamily	*100*	-	*0*	=	*100*	x	*.50*	=	*50*
Institutional	*500*	-	*500*	=	*500*	x	*.50*	=	*250*
Light industrial	*500*	-	*0*	=	*500*	x	*.50*	=	*250*
Commercial	*2,000*	-	*200*	=	*2,000*	x	*.50*	=	*1,000*
Total	*10,000*		*2,000*						*5,000*

* Use forest cover coefficients that represent the amount of forest conserved at a site with adoption of forest conservation or afforestation requirements.

(continued)

Section 3. Results Summary

Total Current Forest Cover	*15,000*	acres		
From Table 4.				
Total Future Forest Cover	*16,000*	acres		
From Section 2.				
Future Forest Increase	*1,000*	acres	7	%

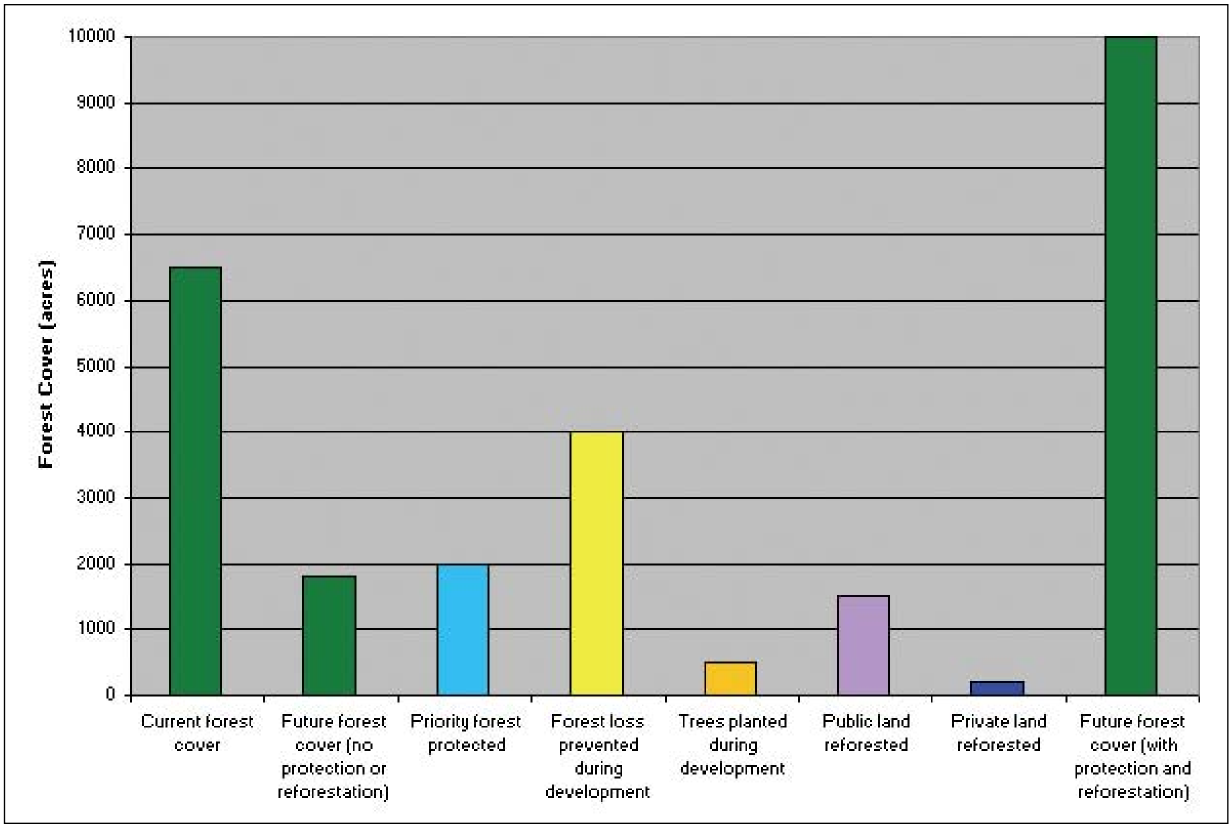


Figure 11. The effect of forest conservation and reforestation on future forest cover

Figure 11 illustrates the effect of priority forest cover objectives on future forest cover compared with future forest cover with no protection or reforestation efforts.

Step 3: Identify Existing Forest and Reforestation Opportunities

Once numerical targets for protection of existing forest and reforestation are identified, the next step involves locating the best sites in the watershed for these activities. In this step, priority forest and reforestation sites are selected for further evaluation in the field based on the inventory of current land cover in the watershed. Due to factors such as budget and land ownership, however, it is not desirable or feasible to pursue each and every forested site for protection, or each and every open area for reforestation. Using the information generated through the inventory of current and future land cover, as well as some additional land use and land owner information, a select number of sites can be identified through the use of a GIS. Table 8 identifies what are typically the best opportunities for each of the seven urban watershed forestry objectives.

Table 8. Types of Land Best Pursued for Urban Watershed Forestry Objectives	
Urban Watershed Forestry Objective	**Best Opportunities**
A. Protect Priority Forests	Large tracts of contiguous, unprotected forest
B. Prevent Forest Loss During Development and Redevelopment	Forest on parcels to be developed
C. Maintain Existing Forest Canopy	Forest on parcels that are already developed
D. Restore Forest Fragments	Protected forests
E. Plant Trees During Development and Redevelopment	Turf areas on parcels to be developed, including streetside planting areas, storm water treatment practices (STPs), property lines
F. Reforest Public Land	Turf areas on publicly owned parcels that are already developed (e.g., parks, schools, stream buffers, STPs, rights-of-way) or undeveloped turf areas (provided reforestation is done in conjunction with protection measures)
G. Reforest Private Land	Turf areas on privately owned parcels that are already developed (e.g, residential lawns, stream buffers, institutional and commercial land)

GIS layers created in Step 1 (current land cover, protection status, development status, zoning and future land cover) are combined with the following layers in this step:

- Property boundaries/land owner information
- Public lands (e.g., schools, parks, rights-of-way)
- Storm water treatment practices
- Vacant land
- Aerial photos
- Natural resource data (e.g., streams, wetlands, floodplains, critical habitats, karst features, steep slopes, erodible soils, monitoring data)
- Cultural, recreational, or historical areas.

Step 3.1 Identify Existing Forests for Further Assessment

To identify existing forests for further assessment, a watershed map that also identifies forested land that may be lost to future development (e.g., unprotected and undeveloped forest land) should be analyzed (Figure 12). It may also be useful to overlay the map with other GIS layers on the map that define constraints on site selection, such as land ownership, transportation corridor or utility restrictions, prior site use (e.g., potential for soil or groundwater contamination), and natural, cultural, and historical resources.

Forests selected for further evaluation are assessed in the field to determine whether they are good candidates for protection or restoration and to select appropriate protection or restoration techniques. In highly urban watersheds where few remaining forests exist, it may not be necessary to whittle down the forested sites to a more manageable number. Criteria for selecting forested parcels for further evaluation include the following:

- Currently unprotected
- Publicly owned or willing land owner
- Contiguous forest greater than a specified acreage (set by municipality, dependent on average size of forest fragments)
- Strategic location in watershed (e.g, is adjacent to existing forest parcel, reforestation site, or protected land; connects or has the potential to connect two existing contiguous forest parcels; has significant natural, historic, cultural or recreational value).

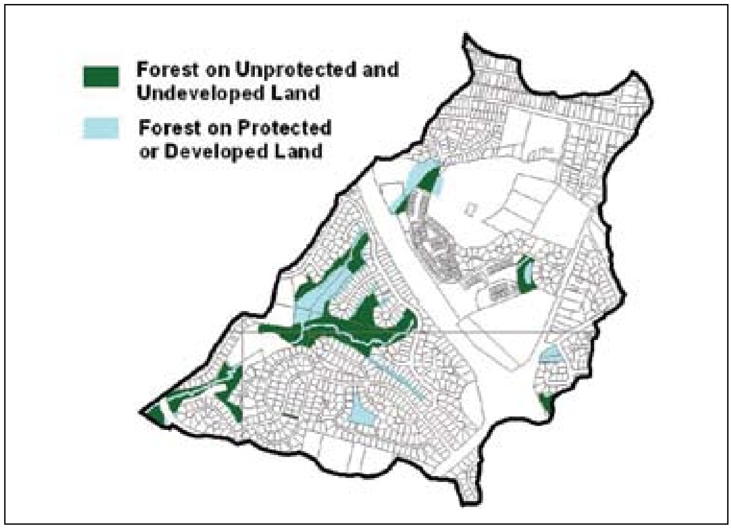


Figure 12. Buildable forest land with potential for future forest loss.

Each community should tailor these criteria for selecting forest parcels to take into account the specific characteristics of their watersheds. The possibility of expanding forested areas or linking them to the stream corridor or other remnants should always be considered when selecting priority forest sites. Owners of large forested tracts may be contacted at this stage to gauge their interest in forest conservation efforts, and to get permission to evaluate their land further.

Step 3.2 Identify Reforestation Opportunities for Further Assessment

To select reforestation sites for further assessment, a map that displays the existing non-forest vegetative cover in the watershed should be analyzed along with property boundaries, vacant lands, public lands, storm water treatment practices, and natural cultural and historical resource information.

Sites with turf cover typically present the best reforestation opportunities because they do not involve extensive removal of vegetation or impervious cover. If the GIS layer of land cover does not distinguish between turf and other types of non-forest vegetation, aerial photos may be used to verify which parcels contain turf. Turf cover typically represents the largest portion of non-forest vegetative cover and can comprise up to 80% of urban pervious cover (CWP, 2000b). Figure 13 shows the distribution of turf cover at the state level across various land uses (composite of MTC, 1996; VASS, 1998; and PTC, 1989).

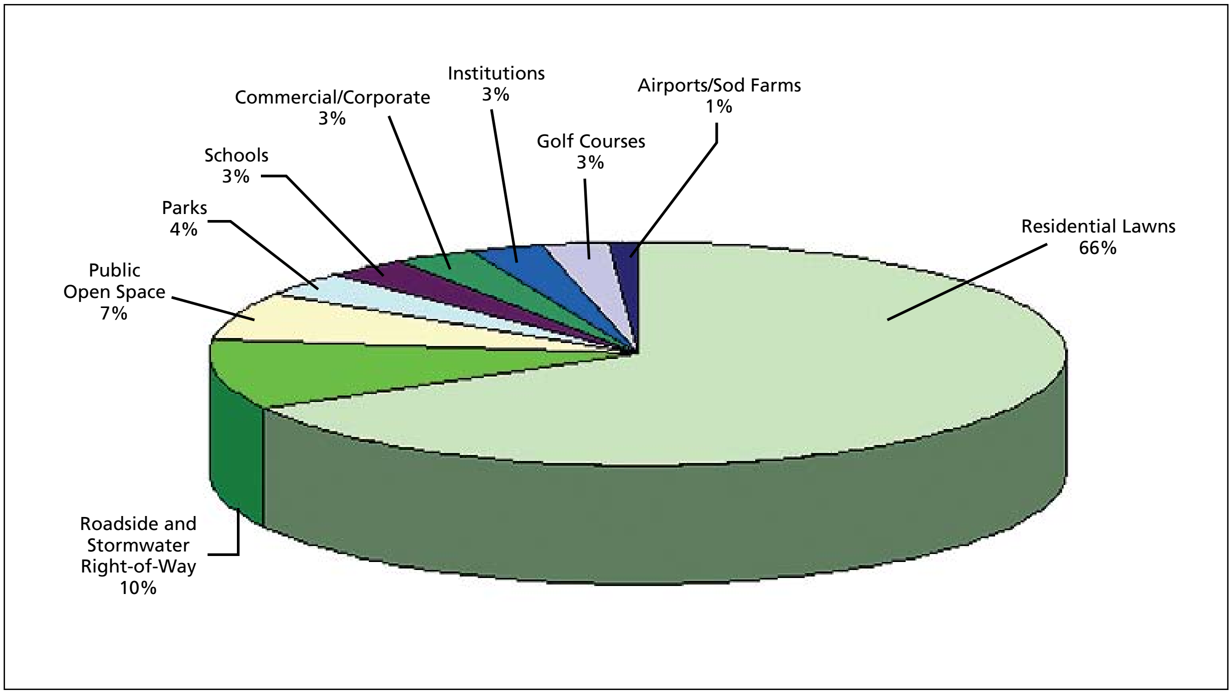


Figure 13. Distribution of turf cover at the state level (composite of MTC, 1996; VASS, 1998; and PTC, 1989)

Figure 13 clearly shows that residential lawns constitute the largest single share of turf cover (about 67%). Public land, such as rights-of-way, open space, parks, and schools, constitute about a quarter of the total turf cover. This distribution will vary from watershed to watershed, but residential lawns and public land are typically the major components.

While reforesting residential lawns may yield the largest increase in watershed forest cover, this can be difficult to accomplish because of the sheer number of landowners involved and potentially small number of homeowners who are willing to convert their turf to forest. If residential lawns do comprise a significant portion of turf cover in the watershed, an education program geared towards homeowners about the benefits of planting trees, combined with a community tree planting or cost-share program, may be the most effective tool for increasing forest cover on residential lots (GFC, 2001). The same approach may be used for private institutions, commercial land, and multifamily housing complexes, which may also have large turf areas that can be reforested. Figure 14 illustrates that while private turf may present opportunities for extensive reforestation, the land is typically in the hands of multiple owners.

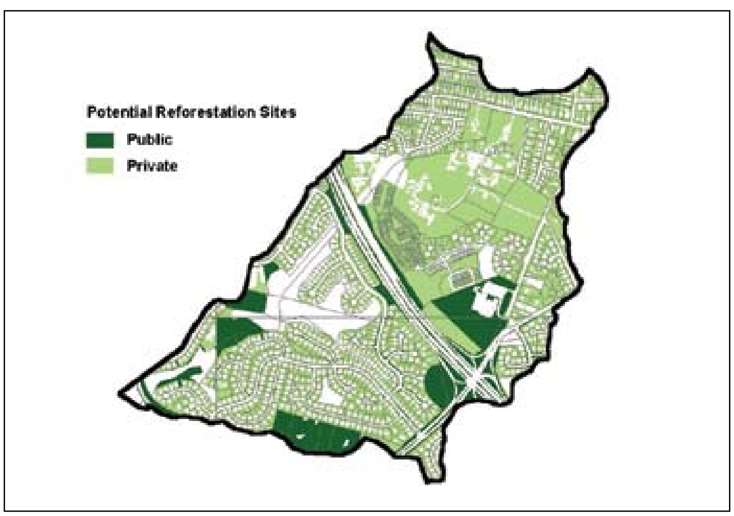


Figure 14. Public and private land with potential for reforestation

Public lands are attractive from the standpoint of reforestation because of their large size and ownership. These include highway cloverleafs and buffers, parks, schools, storm water dry ponds, and utility corridors. Vacant lands and stream corridors provide additional opportunities to reforest the watershed. Criteria for selecting reforestation opportunities for further evaluation include the following:

- Turf cover
- Developed or vacant land
- Publicly owned (e.g., highway cloverleafs, highway buffers, parks, schools, storm water dry ponds, utility corridors)
- Strategic location in watershed (e.g, stream corridor, adjacent to existing forest parcel, reforestation site, or protected land; connects or has the potential to connect two contiguous forest parcels; has significant natural, historic, cultural or recreational value).

Each community should tailor these criteria to select reforestation opportunities that take into account the specific characteristics of their watersheds. For example, a community with a very large number of sites that meet the above criteria may elect to evaluate only turf parcels larger than 2 acres. The possibility of expanding existing forested areas or linking two forest fragments should always be considered when selecting priority reforestation sites.

Step 4: Conduct a Field Assessment of Existing Forest and Reforestation Opportunities

The next step is to select existing individual forest and/or potential reforestation sites for further evaluation in the field to verify their existence and use, determine if they are good candidates for protection, restoration or reforestation, and to collect some basic screening information to rank the sites.

Step 4.1 Conduct a Field Assessment of Existing Forest Fragments

Many methods exist for evaluating the quality of existing forests; however, few are specifically tailored to urban forests. Several forest assessment methods are summarized in Table 9, which address at least some of the potential impacts of development on forests. The priority forests selected in Step 3 should be assessed using one of these methods or an equivalent. The choice of which method to use and how many forested parcels to initially evaluate in the field will ultimately be driven by staff, budget, resources and the level of detail desired.

Table 9. Summary of Forest Assessment Methods			
Forest Assessment Method	**Applicability**	**Description**	**Source**
Unified Subwatershed and Site Reconnaissance (USSR)	Urban upland forests	The Pervious Area Assessment form of the USSR is used to collect basic information about existing forest remnants	Wright and others, (2004)
Woodland Buffer Habitat Assessment	Riparian forest	Evaluates the value of riparian forest for wildlife habitat	Hanssen (2003)
Upland Contiguous Forest Assessment	Upland forests	Designed to evaluate large parcels of contiguous forest to determine which are priorities for conservation	CWP (unpublished)
Maryland's Green Infrastructure Assessment	Regional application	Evaluates hubs and corridors in terms of ecological significance for the purpose of land acquisition	Weber (2003)
Maryland Forest Conservation Act Stand Assessment	Parcel scale	Evaluates forest stands on an individual development site to identify conservation areas	Greenfeld and others, (1991)

Each method collects similar types of information at forest fragments to evaluate the quality of the forest, identify potential restoration opportunities, and rank each site in terms of conservation priorities. These forest characteristics are presented in Table 10.

Table 10. Forest Characteristics Evaluated in Field Assessments	
Characteristic	**Description**
Basic site information	Landowner and use, parcel size, location, protection and development status
Surrounding land uses	Observe adjacent forest or open areas and evaluate potential for connection with these nearby fragments
Dominant species	Dominant tree species or forest association
Forest age	Indicated by successional stage or size class of dominant trees
Vertical structure	Presence of different vertical layers of vegetation such as ground cover, understory, mid-story, and canopy trees. Measure of habitat complexity.
Canopy density and condition	Percentage of forest covered by tree canopy, canopy condition and health.
Herbaceous vegetation	Density and species of herbaceous vegetation, presence of duff layer
Understory vegetation	Density and species of understory vegetation
Invasive species	Density, extent, and species of invasive plant species
Indicator or rare, threatened, or endangered (RTE) species	Species and specific location. Indicator species are intolerant of a decline in habitat quality and are therefore indicators of high quality habitat
Evidence of disturbance	Clearing, trash dumping, erosion, pollution, overbrowsing
Presence of food, water, cover, and habitat	Includes streams, wetlands, snags and cavity trees, large woody debris, conifers, mast species, vernal pools, leaf litter

Basic site information and surrounding land uses are evaluated to assess the feasibility of protecting or restoring the site and to use in ranking the site in terms of its potential to connect other forest fragments or habitat corridors. The remaining characteristics provide an overall indicator of the ecological significance or value of the forest. Most forest assessment methods will include a system for interpreting data collected in the field that results in an actual score or classification of the forest in terms of ecological value.

Step 4.2 Conduct a Field Assessment of Potential Reforestation Sites

Most potential reforestation sites are public or private turf. Turf areas should be assessed in the field to verify their condition, evaluate the feasibility of reforestation, and collect information to prioritize candidate sites. If desired, additional information may be collected at this time to use in developing a reforestation plan for the sites (e.g, detailed soil characteristics). Table 11 summarizes three assessment methods for evaluating urban reforestation sites. Additional information on evaluating planting sites is provided in Part 3 of this manual series, and in Reynolds and Ossenbruggen (1991) and WFC and Morgan (1993).

Table 11. Summary of Reforestation Site Assessment Methods

Reforestation Site Assessment Method	Applicability	Description	Source
Unified Subwatershed and Site Reconnaissance (USSR)	Urban upland pervious areas	The Pervious Area Assessment form of the USSR is used to collect basic information about potential planting sites	Wright and others, (2004)
Unified Stream Assessment	Urban riparian areas with inadequate stream buffer	The Inadequate Buffer form is used to collect basic information about potential planting sites with < 25 foot forested stream buffer	Kitchell and Schueler (2004)
Site Assessment for Urban Tree Planting	Urban planting sites	Detailed site assessment for urban tree planting to use in selecting species and developing a planting plan	Bassuk and others, (2003)

The types of information collected with each assessment method vary with the purpose of the assessment and location(s) in which they apply (upland or riparian). Table 12 provides a summary of the three types of information typically collected during a reforestation site assessment: feasibility factors, ranking factors, and factors to use in creating a reforestation plan.

Table 12. Factors Evaluated in Field Assessment of Reforestation Sites

Factor Type	Description
Feasibility	Landowner and use, site access, potential soil contamination, lack of sun or water, severe and widespread invasive species or overbrowsing, conflicts with infrastructure
Ranking	Size and dimensions of planting area, location in watershed, surrounding land use, potential for connection to nearby forest or protected land, presence of nearby streams, wetlands, RTE species or other sensitive resource
Reforestation Planning	Current vegetative cover, invasive species, trash dumping, soil pH, soil texture, soil compaction, soil drainage, soil salinity, soil depth, distance to water table, light exposure, heat exposure, wind exposure, slope, and potential for damage from vandalism, automobiles, deer, lawnmowers, etc.

The feasibility and ranking factors collected will be used to prioritize sites for reforestation (Step 5) and the reforestation planning factors collected will be used to determine exactly what to plant, where to plant, and when to plan at the site (Step 6).

Step 5: Prioritize Existing Forest and Reforestation Opportunities

The next step in planning to increase forest cover is to prioritize the candidate sites identified in Step 4 for protection, enhancement, and reforestation. The ranking system should take into account the forest cover goals for the watershed, as well as any larger watershed protection or restoration goals that have been defined. The ranking system should also be driven by the resources available for implementing watershed forestry projects, and will be based on results of both the inventory of watershed land cover and the field assessments. Therefore, some factors may be weighted more heavily than others. While the exact ranking system should be defined by the user, some important ranking factors to include are presented in Table 13.

Table 13. Common Ranking Factors to Prioritize Parcels for Protection, Enhancement, and Reforestation

Ranking Factor	Description
Feasibility Ranking Factors	
Land ownership	Prioritize public land, then private land with willing landowners
Access to site	Project may be infeasible if access to site is not adequate for any necessary foot traffic, vehicles, or heavy equipment.
Prohibitive site characteristics	Certain site characteristics may make a project infeasible, such as potentially contaminated soils or insufficient sunlight for plant growth
Environmental Ranking Factors	
Continuity (if forest)	Prioritize sites with uninterrupted cover
Connectivity	Prioritize sites that link or have the potential to link adjacent forest, reforestation sites, or protected lands
Contiguity	Prioritize sites with greater than a specified acreage
Ecological significance	Prioritize sites with high habitat scores, high fish and bug Index of Biotic Integrity (IBI) scores, mature vegetation, rare, threatened, or endangered species, or other sensitive natural resources, or streams identified as restoration priorities
Location in watershed	Prioritize sites located in riparian areas, wetlands, floodplains, steep slopes, erodible soils, recharge areas, or other locations important to watershed hydrology and water quality.
Community Ranking Factors	
Recreational value	Prioritize sites with recreational value
Community acceptance	Prioritize sites that received community support and have a potential base of volunteers to help with tree planting or maintenance (this may entail a public meeting to get community input on projects)
Historic or cultural value	Prioritize sites with significant cultural or historical value
Difficulty Ranking Factors	
Cost	Prioritize sites with the lowest cost per acre
Level of effort	Prioritize sites that require minimal site preparation (soil amendments, removal of invasive species) over those requiring extensive site preparation

Separate prioritization methods may be developed to rank forested sites and reforestation sites. Several examples of detailed prioritization methods for protection, enhancement, and reforestation projects are summarized in Table 14.

Table 14. Summary of Prioritization Methods for Protection, Enhancement, and Reforestation

Prioritization Method	Applicability	Description	Source
Maryland's Green Infrastructure Assessment	Regional application	Prioritizes hubs and corridors for land acquisition based on ecological significance	Weber (2003)
Urban Riparian Restoration Project	Urban riparian areas	Three-tiered ranking system for prioritizing riparian sites for reforestation	Virginia Department of Forestry (1993)
Watershed Analysis Extension for ArcView	Watershed scale	Provides tools for quantitatively ranking land in a watershed by estimated surface water quality impact	de la Cretaz and others, (2003)
Chesapeake Bay Resource Lands Assessment	May be applicable at a variety of scales	GIS-based methods for identifying forests in the Chesapeake Bay watershed that are important for protecting water quality and watershed integrity	Painton-Orndorff and others, (2004)
Forest Areas of Local Importance	County or regional application	GIS-based decision tool to identify critical forest areas for protection	NEGRDC (2004)
Urban Forest Effect (UFORE) Model	Site level	GIS-based tool for selecting the best locations to plant trees to improve air quality and building energy conservation	USDA Forest Service (2004)

Step 6. Develop Recommendations for Meeting Forest Cover Goals

The last step in planning to increase forest cover is to integrate forest cover goals for the watershed in the context of a watershed plan. This plan should include specific recommendations for implementing protection, enhancement, and reforestation techniques at priority sites.

Watershed planning is a unique forest protection tool in that it takes a landscape-level approach to conserving forests based on natural features rather than focusing on jurisdictional boundaries or an individual development site. A watershed plan ideally should be created for every watershed within a jurisdiction that seeks to maintain or increase forest cover and incorporates specific recommendations for how to do this. CWP (1998b) and Schueler (2004) provide detailed guidance on how to create watershed protection plans and subwatershed restoration plans.

A watershed plan should incorporate the forest cover goals developed in Step 2 as well as the priority objectives identified and any related numerical targets. The watershed plan should also include priority sites identified for protection, restoration, and reforestation. Detailed information should be provided for the top priority sites, including the following:

- Specific techniques recommended for protection, enhancement, or reforestation
- Cost estimates for implementation and maintenance
- Potential funders, partners, and other entities who will be involved in project implementation and long-term maintenance (e.g., watershed organizations, homeowners associations or HOAs)
- Implementation schedule.

Step 6 will involve some decisionmaking as to what types of protection, enhancement, or reforestation techniques to use at each priority site. Protection, enhancement, and reforestation techniques are described in detail in Chapter 3.

Chapter 3: Techniques for Maintaining and Increasing Forest Cover in a Watershed

This chapter provides a summary of techniques and further resources for the protection and enhancement of forests and the reforestation of open lands in a watershed. Table 15 lists the techniques according to the corresponding goals and objectives.

Table 15. Summary of Protection, Enhancement, and Reforestation Techniques		
Goals	**Objectives**	**Techniques**
Protect	A. Protect Priority Forests	1. Conservation easements 2. Land acquisition 3. Transfer of development rights
	B. Prevent Forest Loss During Development and Redevelopment	4. Bonus and incentive zoning 5. Clearing and grading requirements 6. Forest conservation regulations 7. Open space design 8. Overlay zoning 9. Performance-based zoning 10. Storm water credits 11. Stream buffer ordinances
	C. Maintain Existing Forest Canopy	12. Protection of significant trees 13. Tree removal restrictions for developed areas
Enhance	D. Enhance Forest Fragments	14. Increase forest area where possible 15. Increase habitat diversity 16. Manage deer 17. Protect soils from erosion and compaction 18. Provide food, cover, and nesting sites for wildlife 19. Reduce or eliminate invasive species 20. Remove trash and prevent dumping
Reforest	E. Plant Trees During Development and Redevelopment	21. Landscaping requirements 22. Planting trees in storm water treatment practices 23. Planting trees in other open areas 24. Shading and canopy requirements
	F. Reforest Public Land	25. Allow natural regeneration 26. Actively reforest public lands
	G. Reforest Private Land	27. Education 28. Incentives for tree planting 29. Stewardship and neighborhood action

Techniques for Protecting Forests

Different techniques are used to protect existing forests. Generally, these fall into three categories depending on the stage of development. Techniques related to Objective A, Protect Priority Forests, focus on techniques to protect large tracts of forest that are currently undeveloped. Techniques related to Objective B, Prevent Forest Loss During Development and Redevelopment, focus on limiting the clearing of forests during the actual construction process. Techniques related to Objective C, Maintain Existing Forest Canopy, include techniques that prevent landowners from clearing forests on land that has already been developed. Most techniques are regulatory tools that local governments can adopt to protect forests during each stage of development. One exception is the urban forestry management plan, which is described in Box 17.

This section briefly describes each technique and includes relevant links to model regulations, example ordinances (see Box 18), and comprehensive references. Additional information about many of these techniques can be found in ELI (2000), Palone and Todd (1998), Georgia Forestry Commission (2001), and Wenger and Fowler (2000).

BOX 17. URBAN FORESTRY MANAGEMENT PLANS

Urban forestry management plans are comprehensive plans for managing the urban forest within a particular jurisdiction. These plans can be used to set goals for forest canopy cover, conduct tree inventories, make recommendations for new tree plantings, provide species lists, and outline methods for managing the urban forest. While these plans may not be regulatory per se, they are similar to comprehensive plans in that they provide the framework upon which specific ordinances and other regulations may be built. The City of Roanoke, Virginia has an Urban Forestry Plan that contains many of these elements and is a good example of comprehensive urban forest management. This plan is available online at www.roanokegov.com/WebMgmt/ywbase61b.nsf/vwContentFrame/N254GHSJ053LWODEN.

BOX 18. A NOTE ABOUT ORDINANCES

When developing a forestry ordinance, it is always important to ensure that the language clearly defines the following factors: the purpose of the ordinance, who is subject to it, penalties for violation, who is responsible for enforcement of penalties, and allowable enforcement actions. General guidance on how to design tree-related ordinances or evaluate existing ordinances is provided in the following references:

- International Society of Arboriculture Guidelines for Developing and Evaluating Tree Ordinances:
  http://phytosphere.com/treeord/index.htm
- International Society of Arboriculture. 1990. *Municipal Tree Manual. Urbana, IL*
  Comprehensive guide to drafting and revising a municipal tree planting and care ordinance. Discusses management standards and includes sample ordinances.
- Urban Forestry South Urban Tree Ordinance Index:
  www.urbanforestrysouth.org/ordinances/index.asp
- TREEORD Software: www.mnstac.org/RFC/treeord_software.htm
- McElfish, J. M., Jr., 2004. Nature-Friendly Ordinances. Environmental Law Institute. www.eli.org
- Louisiana State University Greenlaws Web site: www.greenlaws.lsu.edu/

Protecting Priority Forests

Large tracts of high quality forest or those potentially valuable to watershed functions can be protected from future development through conservation easements, land acquisition, or transfer of development rights.

1. Conservation easements

Conservation easements are conveyances of development rights from a property's landowner to a municipality, land trust, or other nonprofit organization. The easement may be purchased or donated and typically grants the seller a reduction in taxes. The landowner still retains use, occupancy, and ownership of the land itself, but is limited in the ability to develop the land for the term of the easement (which may be permanent or may expire after a specified number of years). The terms of the easement may also dictate what types of activities are allowable on the land, and the easement is transferable with the land if sold.

- Land Trust Alliance (LTA): www.lta.org
- Model Conservation Easement: www.stormwatercenter.net/Model%20Ordinances/model_conservation_easement.htm.

2. Land acquisition

Land acquisition is outright acquisition of title to forested lands by a municipality, land trust, or other nonprofit organization. This is an expensive way to protect forested lands, but it guarantees long-term protection from development. As owners of the land, land trusts have control of management and use of the land (unlike conservation easements). The Nature Conservancy and the Trust for Public Land are two national organizations that act as land trusts.

- The Nature Conservancy: www.tnc.org
- Trust for Public Land: www.tpl.org
- The Conservation Fund: www.conservationfund.org.

3. Transfer of development rights

Transfer of development rights (TDRs) is a land use management technique that transfers development potential from environmentally sensitive areas such as forests to specific areas designated for growth. TDRs are based on a market-driven incentive program where it is possible to sell development potential without actually buying or selling land. Once a TDR occurs for a property, further development can never occur on that land. Landowners in preservation areas are compensated for lost development potential (CWP, 1998a).

- Sarasota, FL,Transfer of Development Rights Ordinance: www.stormwatercenter.net/Model%20Ordinances/misc_sarasota.htm

Preventing Forest Loss During Development and Redevelopment

Several regulatory tools can be applied to directly or indirectly reduce forest clearing during construction as well as to prevent inadvertent injury to trees. Techniques include these: bonus or incentive zoning, clearing and grading requirements, forest conservation and protection regulations, open space design, overlay zoning, performance-based zoning, storm water credits, and stream buffer ordinances. Each technique is described below.

4. Bonus and incentive zoning

Bonus and incentive zoning encourages developers to conserve environmental resource areas such as forests. In this technique, a developer is granted the right to build more intensively on a property or is given some other bonus in exchange for conserving a portion of the site in natural vegetation or providing an amenity, such as trails or a park that the community feels would be beneficial (CWP, 1998a). For more information on bonus and incentive zoning, consult McElfish (2004).

5. Clearing and grading requirements

Regulations that limit the maximum amount of clearing that can occur at a development site can be an effective forest conservation technique. For example, a developer may be restricted to clearing no more than 25% of a site. Alternatively, the ordinance might state that the grading contractor or developer must use site fingerprinting, a technique in which clearing and grading is reduced by limiting disturbance to the minimum necessary for the construction of buildings and roadways. At a minimum, clearing and grading may be restricted within a specified distance (e.g., 25 to 50 feet) of all streams. In addition, soil from forested areas that are cleared during development should be stockpiled and replaced so that new vegetation will have healthy soil in which to grow. Part 2 of this manual series contains more detailed information on site fingerprinting and other techniques to protect trees at a development site.

- City of Olympia, WA, Clearing and Grading Ordinance:
  www.stormwatercenter.net/Model%20Ordinances/esc_clearing_ordinance.htm.

6. Forest conservation regulations

Forest conservation and protection regulations require the retention and protection of trees and forests on a development site. These regulations establish specific criteria for identifying which trees and forests should be conserved, and prescribe methods to protect these stands during the construction process.

Criteria for conserving forests on a development site are often expressed as a minimum percentage of existing forest (e.g., conserve at least 25% of any existing forest on the site), a minimum percentage of the site (e.g., at least 25% of the site must be forested—reforestation may be necessary to meet these goals), or as a tree size threshold (e.g., conserve all trees greater than 6 inches in diameter at breast height outside of the building and pavement footprint). Trees to be protected can also be identified based on age, species, historic significance, ecological value, esthetics, location, or other factor. Special trees such as heritage, champion, or specimen trees are often protected through these ordinances.

Forest protection regulations typically require the contractor for a development site to create a tree protection plan. The plan delineates forest stands, defines the limits of disturbance, requires protective barriers be installed around trees to be protected, and posts signs to inform contractors of the tree protection area (Figure 15). These regulations protect trees from unnecessary damage during construction, such as mechanical injury to roots, trunks, or branches; compaction of soil; or changes to existing grade that may expose or suffocate roots.

To ensure long-term protection of trees, forest conservation and protection regulations may require permits for removal, encroachment, or pruning of trees. They may also require posting of signs to inform residents of the tree protection areas and should include enforceable penalties for encroachment on tree protection areas.

- American National Standards Institute Tree Protection Standards: http://webstore.ansi.org/ansidocstore/dept.asp?dept_id=30
- Frederick County, MD, Forest Conservation Ordinance: www.stormwatercenter.net/Model%20Ordinances/buffer_model_ordinance.htm
- Maryland Forest Conservation Act: www.dnr.state.md.us/forests/programs/urban/explained.html
- City of Pasadena, CA, Tree Protection Guidelines: www.ci.pasadena.ca.us/publicworks/PNR/TreeOrdinance/protectionGuidelines.asp
- International Society of Arboriculture. Avoiding Tree Damage During Construction: www.isa-arbor.com/consumer/avoiding.html
- Minnesota Department of Natural Resources. Conserving Wooded Areas in Developing Communities: Best Management Practices in Minnesota: http://files.dnr.state.mn.us/forestry/urban/bmps.pdf
- Tree Protection Ordinance for Chapel Hill, NC: http://ourworld.compuserve.com/homepages/DoanePerry/ChapelHillNC.htm.

Figure 15. Sign posted at construction site informs workers of forest protection area.

7. Open space design

Open space design is a compact form of development that concentrates density on one portion of the site in exchange for reduced density elsewhere. Open space design allows for the preservation of forests, using less space for streets, sidewalks, parking lots, and driveways (Figure 16). Requirements in an open space design ordinance generally set aside a percentage of the site for active or passive open space area (e.g., ballfields or trails). Minimum lot sizes, setbacks, and frontage distances are relaxed to provide this common open space. Open space regulations can protect existing forests, provided the regulations identify allowable types of vegetation, minimum area, native species, allowable uses, and maintenance responsibilities. An open space design ordinance should also specify that the open space be maintained in a natural condition.

- Stormwater Manager's Resource Center. Open Space Design Model Ordinance: www.stormwatercenter.net/Model%20Ordinances/open_space_model_ordinance.htm.

Figure 16. This open space design contains areas of preserved forest (Source: Randall Arendt)

8. Overlay zoning

Overlay zoning superimposes additional regulatory standards or development criteria onto existing zoning provisions. Overlay zones can be created to protect particular resources, such as forests, wetlands, or historic sites. The provisions of the overlay zone incorporate mandatory requirements that restrict development in some way to reach the desired level of forest conservation or other goal. This land use management technique gives a community legal control without having to purchase land (CWP, 1998b; Palone and Todd, 1998; McElfish, 2004).

9. Performance-based zoning

Performance-based zoning is designed to ensure an acceptable level of performance within a given zoning district, such as providing a certain open space/development ratio, an impervious area target, or a desirable density. Performance factors include storm water runoff quality and quantity criteria, protection of wildlife and vegetation, or traffic and noise generation limits. The developer is given flexibility and control over development as long as these criteria are met (CWP, 1998a; Palone and

Todd, 1998). Performance-based zoning can be used to protect a specified percentage of forested land. For more information on performance-based zoning, see McElfish (2004).

10. Storm water credits

A storm water credit system provides incentives to developers, designers, and builders, to implement site design techniques that cause less impact to aquatic resources by conserving forests, reducing impervious cover, and reducing storm water runoff. By taking advantage of the credit system, developers can reduce the storm water management requirements for quantity or quality or both. The credit system directly translates into cost savings to the developer by reducing the size of storm water storage and conveyance systems required.

Credits may be given for conservation of natural areas, reforestation, stream buffers, forested filter strips, green rooftops, and nonstructural techniques that help to reduce storm water runoff. Storm water credits for conservation of natural areas rewards protection of natural vegetation or critical resource areas on a development site. Under this credit, the developer may subtract forest conservation areas from the total site area when computing the water quality volume and the recharge volume.

- Maryland Stormwater Design Manual: www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp.

11. Stream buffer ordinances

Stream buffer ordinances require the conservation and protection of existing forested stream buffers on a development site, and may also require reforestation of stream corridors that are currently lacking tree cover. Forested buffers provide shade for the stream, protection from erosion, habitat for wildlife, and recreational opportunities. Stream buffer ordinances should set criteria for buffer width, vegetation, allowable uses, and long-term maintenance. More information about buffer ordinances can be found in CWP (2000a), Wenger (1999), and Cappiella and Schueler (2001).

- Storm Water Manager's Resource Center Stream Buffer Model Ordinance: www.stormwatercenter.net/Model%20Ordinances/buffer_model_ordinance.htm

- Center for Watershed Protection. 2000. The Architecture of Urban Stream Buffers. www.stormwatercenter.net/Library/Practice/39.pdf

- Wenger, S. J.; L. Fowler, 2000. Protecting Stream and River Corridors: Creating Effective Local Riparian Buffer Ordinances. Athens: University of Georgia. www.cviog.uga.edu/pprs/paper-streams.pdf

- Montgomery County, PA, Model Ordinance for Riparian Corridor Conservation District: www.pawatersheds.org/techresources/bufferordinance.pdf.

Maintaining Existing Forest Canopy

In neighborhoods that have already been built-out, existing tree canopy may decline over time if trees are removed or ruined by topping or other poor maintenance practices. While regulation of forest stands on developed private lands may not be practical or desirable, individual trees can be protected by awarding special status to significant trees, such as champion trees, or by regulating the removal and replacement of existing trees.

12. Protection of significant trees

By explicitly providing special status to significant trees such as specimen or champion trees, communities may be able to provide a higher level of protection to such trees. The Cape Cod Commission (2003) defines a specimen tree as “a native, introduced or naturalized tree, which is important because of its impacts on community character, its significance in the cultural landscape or its value in enhancing the function of wildlife habitat.” A champion tree is the largest tree of its species within a particular county, state, or other jurisdiction (TERRA, 2003; Figure 17).

Other significant trees may be defined by characteristics such as size, species, age, historical significance, ecological value, esthetics, or location. Alternative ways that are used to identify significant trees include: “heritage,” “historic,” “landmark,” and “legacy.”

Significant trees can be protected by identifying and registering them with the local natural heritage department or registrar of champion trees. Registration will keep them from being removed (if the land is not already protected through some other means). Another protection measure is designating an area of no disturbance around a tree. An ordinance may also be created to specifically protect these valuable trees by defining penalties associated with unauthorized damage or removal of an individual tree.

While protecting individual trees probably does not maintain a significant amount of canopy, a good champion tree program can serve to create public enthusiasm about conserving trees, educate citizens about trees, promote awareness of tree benefits and foster respect for the beauty and historical significance they possess.

- Defining Special Trees: Heritage, Historic and Landmark Trees: http://phytosphere.com/treeord/heritage.htm
- National Register of Big Trees: www.americanforests.org/resources/bigtrees/.

Figure 17. Specimen tree protected during construction. (Photo: Al Todd)

13. Tree removal restrictions for developed areas

Tree removal restrictions are ordinances or other regulatory measures that require a permit to remove, relocate, prune or otherwise damage trees within a specified area or of a specified size or species. These ordinances may also require replacement of any trees that are removed.

Recognizing that trees reduce runoff and provide other watershed benefits, the Council of the City of Takoma Park, MD, has instituted tree removal regulations. The Takoma Park ordinance requires a permit to remove “urban forest trees,” and requires residents to replace any urban forest tree removed or excessively damaged. This ordinance also requires the replacement of trees that were initially recorded as trees to protect during construction but were subsequently damaged or cut down. All replacement trees must be equal or superior to the original tree with respect to species quality, shade potential, and other characteristics, and it must be from nursery stock with a 1-year guarantee. Enforcement is an important factor to consider when implementing tree removal restrictions.

- City of Takoma Park, MD, Tree Ordinance: www.207.176.67.2/pw/treeordinance.html.

Techniques for Enhancing Remaining Forest Fragments

While regulatory tools can prevent a forest from being cleared, enhancement may still be needed to improve its value for wildlife (provide food, water, cover, and nesting sites), improve tree growth and canopy condition, and guarantee the long-term perpetuation of forest vegetation. Urban forest fragments present many opportunities to restore the condition and function of an urban forest. Enhancement techniques increase and improve wildlife habitat and improve conditions for tree growth to ensure long-term sustainability of the forest. This section summarizes techniques for restoring and enhancing forest fragments and includes links to relevant resources. Much of the information in this section was adapted from Hanssen (2003) and Adams (1994).

Existing urban forest fragments on protected lands in the watershed can be enhanced by expanding the forest area, increasing habitat diversity, managing deer, providing food, cover and nesting sites for wildlife, reducing or eliminating invasive species, protecting soils from erosion and compaction, and by removing trash and preventing dumping.

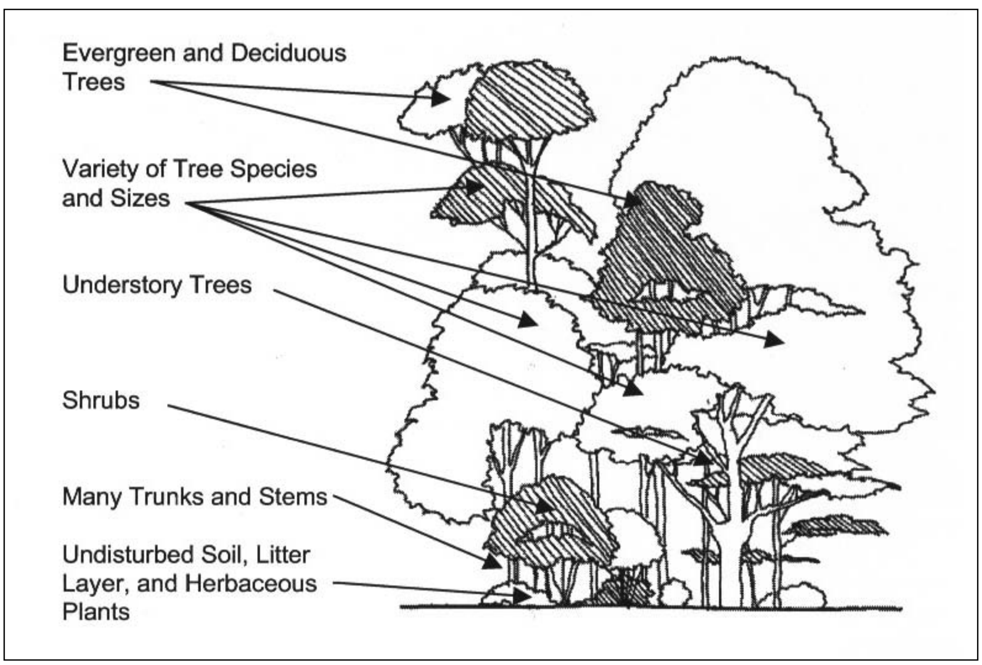


Figure 18. Example of forest with good habitat diversity and vertical structure (Adapted from Head and others, 2001, p. 41)

14. Increase forest area where possible

Forest area can be increased incrementally over time by strategically reforesting areas around remnants or gaps within remnants, or by simply shrinking the edges that are routinely mowed. These small, gradual increases will increase contiguity and benefit wildlife and will not significantly reduce the amount of usable land for the landowner. Cumulatively, these small increases in forest area can significantly increase watershed forest cover.

15. Increase habitat diversity

Urban forest fragments often lack the diversity of habitat common to their rural counterparts. One measure of habitat diversity is vertical structure, which evaluates the variety of vertical vegetative layers in a forest such as overstory, mid-story, understory, and herbaceous vegetation. Figure 18 illustrates a forest with high habitat and species diversity. Urban forest fragments often lack an understory, either due to deer overbrowsing or removal by landowners who want easy access through the forest. Planting understory species in these areas is one way to increase the diversity of habitat in a forest, and native wildlife will be best accommodated by using native tree species. Simply allowing the understory to come back naturally is an even better approach, provided steps are taken to protect the new plants from deer browse, invasives and encroachment, and trampling.

Another opportunity for increasing habitat diversity occurs at the forest edge, where edge habitat exists at the border between the forest and an adjacent land use. If the adjacent land use is pervious (e.g., field or lawn), the edge habitat can be improved by creating a soft edge or transition rather than a hard edge or abrupt change from forest to field. The soft edge can be achieved by removing specific trees along the inside edge of the forest, planting new shrubs and small trees just outside the forest edge, or allowing a strip of land just outside the forest edge to regenerate. This will provide a gradual transition from herbaceous cover to shrubs and small trees to tall trees (Figure 19). This gradual transition provides a greater diversity of habitat types and also reduces predation and nest parasitism along the forest edge (Hanssen, 2003).

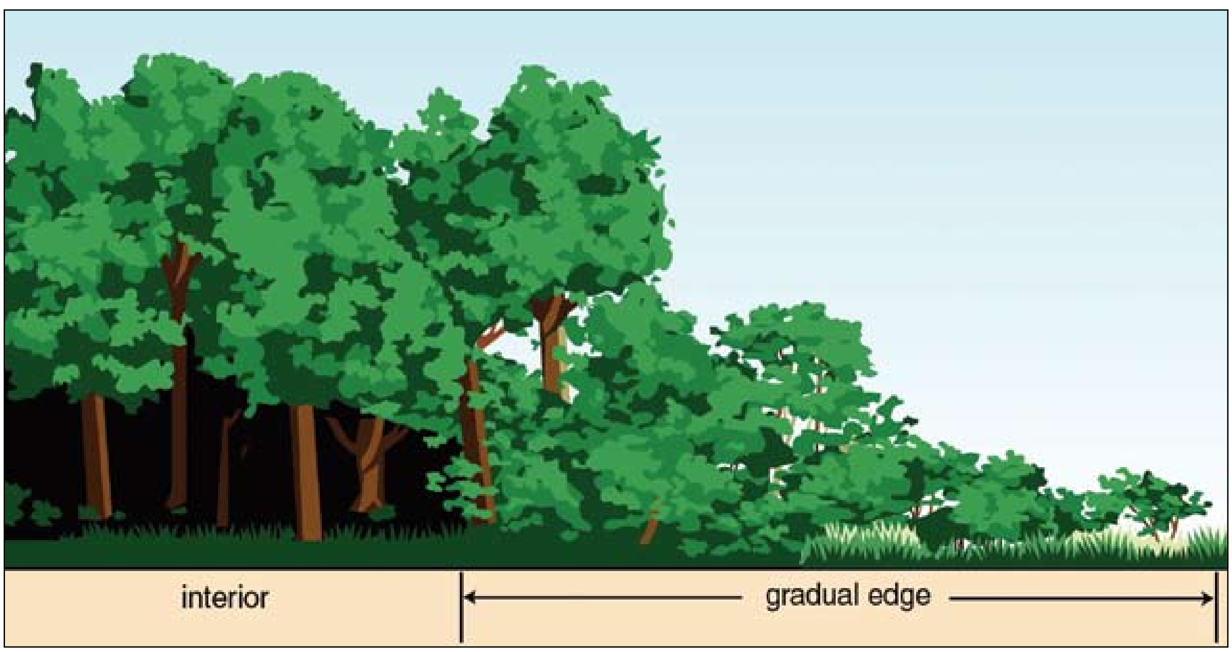


Figure 19. A soft or gradual forest edge provides a gradual transition from forest to field and benefits wildlife . (Source: FISRWG, 1998, p. 8-21)

Woody debris and leaf litter also provide unique habitat features within a natural forest, but may be eliminated in urban forest fragments because landowners wish to “clean up” the debris. A simple method to restore habitat diversity is to leave the woody debris and leaf litter. Woody debris from downed trees or fallen branches should be left in place as they are a source of food for insects and fungi and provide habitat for amphibians, reptiles, and small mammals. Woody debris and leaf litter also contribute organic matter to the soil, which improves water retention and infiltration, and recharges groundwater.

Vernal pools and spring seeps provide two additional types of aquatic habitat within a forest. Vernal pools are small depressions within a forest that temporarily pond water, typically during winter (Figure 20). They provide habitat for amphibians, waterfowl, insects, and crustaceans. Spring seeps are areas where water from below ground flows to the surface to form small streams. These are important for wildlife because they provide a fresh source of water year round. A 50 foot undisturbed buffer is needed to protect vernal pools and spring seeps. Enhancing the buffer around these natural features is another restoration method that improves habitat. Alternatively, vernal pools can be created if none exists.

Figure 20. A vernal pool in winter
(Source: Tiner and others, 2002)

- The Vernal Pool Association: www.vernalpool.org.

16. Manage deer

Deer overpopulation is common in urban and suburban areas where there are no natural predators for deer, and hunting is restricted due to safety concerns. Urban forests also tend to have a large proportion of edge habitat, in which deer thrive (MD DNR, 1998).

Figure 21. Deer exclosure shows heavy browsing of unprotected understory vegetation in forest on right.

Deer browse primarily on woody plants, so a large deer population can essentially deplete the forest of native understory or midstory vegetation. An overbrowsed forest may have a characteristic browse line about 4 to 5 feet high, under which no green leaves are present (evident only during the growing season) or may have all unprotected understory vegetation removed. (Figure 21). Several methods exist to control deer populations and manage their impacts on forests, including hunting, sterilization, fencing, and other barriers and repellents

- Deer in Maryland: www.dnr.state.md.us/wildlife/deerhunting.asp

- Montgomery County Deer Management Work Group 2004. Comprehensive Management Plan for White-Tailed Deer in Montgomery County, Maryland: Goals, Objectives, Implementation. Silver Spring, MD.
  www.mc-mncppc.org/Environment/deer/DEERPLAN%20update%208-2004.pdf.

17. Protect soils from erosion and compaction

Forest soils can be protected from erosion and compaction by restricting access and use. One example is to limit access to designated trails only and to restrict ATV use entirely. Trails should be designed properly to prevent erosion, and special care must be taken in areas with steep terrain. For more information on trail design, see TCF (1993). Another way to improve forest soils is to ensure that the leaf litter layer is not disturbed. Leaf litter contains organic matter that improves water retention and infiltration. Finally, significant inputs of storm water to the forest fragment should be managed to prevent erosion from high flows.

18. Provide food, cover, and nesting sites for wildlife

To encourage desirable wildlife in the urban forest, such as woodpeckers, wood ducks, owls, bluebirds, chipmunks, and foxes, adequate food, cover, and nesting sites must be present. Plant species that provide food, cover, or habitat for specific wildlife species can be planted, or artificial structures that provide cover or nesting sites can be created. These include mast species, brush piles, evergreens, snags and cavity trees, and nesting structures.

Mast species are tree species that produce fruits, nuts, seeds, and other sources of food for wildlife. A healthy forest should have a continuous supply of 40- to 80-year-old healthy mast-producing species (Hanssen, 2003). Examples of mast species are oak, cherry, hickory, beech, and walnut. Many other native plants provide food or habitat for specific wildlife species, and these should be planted or encouraged wherever possible. The growth of desirable species, such as mast species that already have a foothold in the forest, can be encouraged by releasing them from competition. This means removing any nearby competing vegetation on at least three sides. Mast species can also be encouraged by planting new trees.

Figure 22. Brush pile

Brush piles (Figure 22) are made of brush, tree branches, and cut shrubs and serve as cover for wildlife such as rabbits, squirrels, chipmunks, foxes, and songbirds (Hanssen, 2003). Brush piles are particularly important in a forest that lacks understory because they may provide the only shelter for these animals. Brush piles should be built close to a water or food source. Evergreens also serve as cover for wildlife in winter.

- Maryland DNR Wild Acres Program. Brush Piles: www.dnr.state.md.us/wildlife/wabrush.asp
- National Wildlife Federation. Backyard Habitat: www.nwf.org/backyardwildlifehabitat/logpile.cfm.

Snags and cavity trees are dead or partially dead trees that are still standing. Unless they pose a safety hazard, snags should be left standing because they provide habitat for certain species, such as woodpeckers, wood ducks, bluebirds, hawks, and owls. These animals typically feed on insects and can help control insect infestation in the forest.

- How is a Dead Tree Good? www.fs.fed.us/r6/nr/wildlife/animalinn/goodtree.htm
- Maryland DNR Wild Acres Program. Snags and Logs: www.dnr.state.md.us/wildlife/wasnags.asp.

Nesting structures can be built and installed in the forest for species of birds that nest in cavities such as bluebirds. There are various types of nesting structures specifically designed for particular bird species.

- Maryland DNR Wild Acres Program. Eastern Bluebirds: www.dnr.state.md.us/wildlife/wabluebird.asp
- Ducks Unlimited: www.ducks.org/conservation/duck_box_plans.pdf
- Bat Conservation International: www.batcon.org.

19. Reduce or eliminate invasive species

Another method of restoring forest fragments is to improve the conditions for existing desirable vegetation, to ensure their long-term survival. This includes releasing trees and shrubs from competition by thinning, managing deer populations, and controlling invasive plant species.

An invasive species is defined as a species that is nonnative (alien) to the forest ecosystem and whose introduction causes or is likely to cause economic or environmental harm. Control of invasive plant species includes prevention, removal, and monitoring. Introduction of invasive species can be prevented through education programs and good housekeeping practices that prevent the inadvertent introduction or spread of plant seeds and parts by humans. Another prevention method is to minimize disturbance, which may make forests more susceptible to invasion. If invasive species are present, they can be removed through mechanical, chemical, or biological methods. The method selected will depend on the species characteristics, level of infestation, site characteristics, and resources available. The site should be monitored closely so any new invasives can be removed immediately. For more information on specific methods to control invasive species, see Part 3 of this manual series.

- Invasive Species: www.invasivespecies.gov
- Plants Database: http://plants.usda.gov
- The Nature Conservancy's Weed Control Methods Handbook: Tools and Techniques for Use in Natural Areas: http://tncweeds.ucdavis.edu/handbook.html.

Figure 23. Urban forest fragment with illegal dumping

20. Remove trash and prevent dumping

Urban forest fragments often become dumping grounds for trash, building rubble, and unwanted furniture or appliances. Illegal dumping often occurs in these poorly lit areas, particularly along the forest edges and near access trails (Figure 23). Forest fragments can be improved simply by removing the trash and rubble, provided measures are taken to prevent future dumping. These include installing lighting and posting *No Dumping* signs with fines for violation. Cleanup of trash and rubble can be done with volunteers if the volume of trash is minimal and if access and safety are not a concern. Heavy equipment or a hazardous materials (HAZMAT) crew may be needed to remove larger volumes of trash or potentially hazardous material.

Techniques for Reforesting Watersheds

Forest gains can be sharply increased through systematic reforestation of open lands throughout the watershed. Techniques to increase watershed forest cover can be used to meet three of the seven objectives of urban watershed forestry. Objective E, Plant Trees During Development and Redevelopment, either requires or encourages developers to plant trees at development sites, often in places not typically considered for reforestation. Objective F, Reforest Public Land, primarily focuses on reforesting large parcels of public lands that have already been developed, such as schools, parks, and highway and storm water rights-of-way (Figure 24). Objective G, Reforest Private Land, includes techniques to encourage widespread tree planting on feasible locations within individual yards or property that have already been developed.

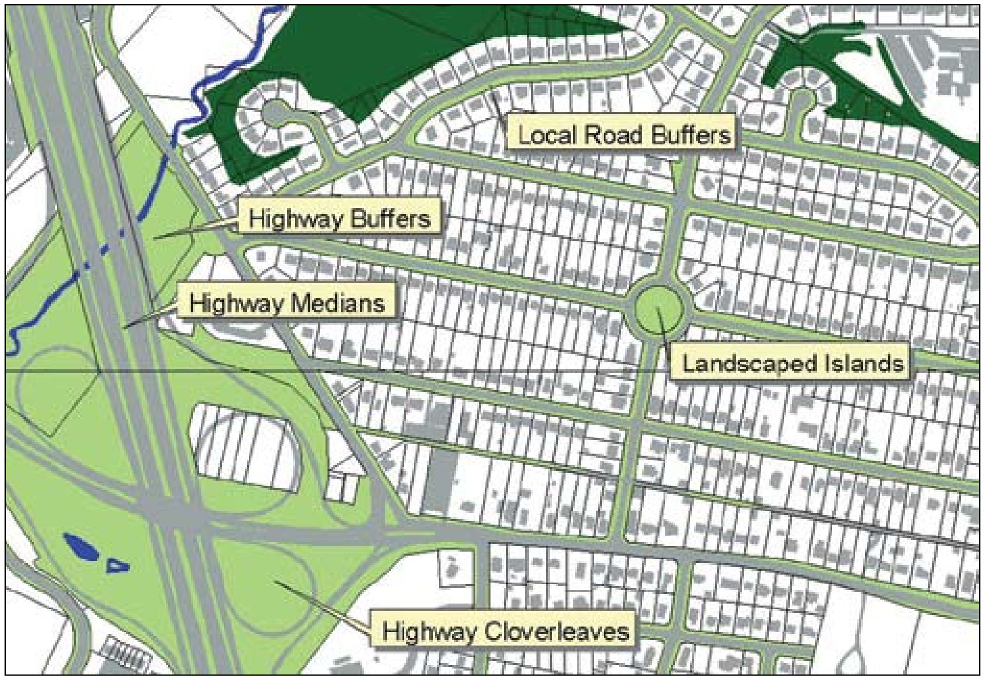


Figure 24. Highway and local road rights-of-way provide opportunities for reforestation on public land

Each technique is summarized in the ensuing section, including any relevant resources. More guidance on implementing reforestation projects, including site preparation, species selection and maintenance, is provided in Part 3 of this manual series. Specific guidance on reforesting the following land uses is provided in Chapter 4:

1. Highway rights-of-way
2. Residential lawns
3. Parks
4. School grounds
5. Storm water dry ponds
6. Streams and shorelines
7. Utility corridors
8. Vacant lots.

Planting Trees During Development and Redevelopment

Four techniques can be applied to encourage developers to plant trees during development and redevelopment projects. Two are regulatory in nature and are adopted by local governments to either directly or indirectly require tree planting in new developments. The other two techniques are simply opportunities that can be applied by the developer to increase tree cover at the development site. These techniques are summarized below and include landscaping requirements, shading and canopy ordinances, planting trees in storm water treatment practices, and planting trees in other open spaces.

21. Landscaping requirements

Landscaping ordinances regulate how much of a nonresidential development site must be landscaped. Most commercial and industrial areas are required to have some type of landscaping, and it may be set as a percentage of the site, an area per number of parking stalls, a number of trees per street length, or other designation. Landscape ordinances typically provide guidance on species selection; plant spacing; setbacks from buildings, pavement, and utilities; planting plan development; and maintenance schedules. While landscaping ordinances do not specifically require the protection of trees and forests, they can act as incentive for developers to conserve existing trees to avoid having to plant new ones to meet landscaping requirements.

- City of Chicago, IL, Landscape Ordinance: www.cityofchicago.org/Environment/CityTrees/LandscapeOrdinance.html
- San Antonio,TX, Landscape Ordinance: www.sanantonio.gov/dsd/pdf/tree_landscapeOrdinanceBrochure.pdf.

22. Shading and canopy ordinances

Shading or canopy ordinances are essentially landscaping ordinances that define planting requirements by the amount of shade created rather than the area planted. These regulations require that a certain portion of a parking lot or street be shaded by tree canopy after a specified time period (typically 15 years). These regulations are popular in arid regions where shading can significantly reduce heat effects. In Sacramento, Davis, and Los Angeles, California, the shade tree ordinance requires 50% of the total paved area to be shaded within 15 years of issuing the development permit. A recent assessment found that these requirements are not actually being met, however, which means that additional planning must be put into how these ordinances are implemented and enforced (McPherson, 2001). Shading ordinances often provide recommended species lists and 15-year crown projection areas of these species to assist site planners in calculating the future shaded area.

- Sacramento, CA, Shade Tree Ordinance: www.energy.ca.gov/coolcommunity/plshade.html
- City of Sacramento, CA, Parking Lot Shading Design and Maintenance Guidelines: www.cityofsacramento.org/planning/longrange/shading_guide.pdf.

23. Planting trees in storm water treatment practices

Urban development sites provide many opportunities to plant new trees, such as storm water treatment practices, which provide water quality treatment and storage of storm water runoff from impervious surfaces. Many storm water treatment practices have not traditionally been considered appropriate locations for planting trees. Research on the benefits of trees, however, shows they have enormous potential to improve the efficiency of these practices through nutrient uptake and runoff reduction.

To encourage tree planting in storm water treatment practices, guidance must be provided to developers on selecting appropriate species, identifying areas suitable for planting, and making any necessary modifications to the design or planting environment. Part 2 of this manual series includes detailed guidance on planting trees in storm water treatment practices.

24. Planting trees in other open spaces

Other open spaces at a development site that make good candidates for tree planting and are often underutilized include local road rights-of-way, landscaped islands in cul-de-sacs or traffic circles, and parking lots. Private lawn areas also provide space for tree planting, but developers typically have no incentives to plant new trees there. Developers are usually required, however, to landscape certain portions of roadside strips and parking lots and can meet these landscaping regulations while increasing tree canopy at the same time. Part 2 of this manual series provides detailed guidance on planting trees at development sites.

Reforesting Public Land

Public lands often present the best opportunities for reforestation in a watershed, either through natural regeneration or active reforestation. Reforesting public lands allows the entire community to enjoy the recreational, educational, and esthetic benefits of forests. Undeveloped public lands may also be reforested, provided some measures are taken to ensure long-term protection of the land from development. Public parks also afford a measure of long-term protection to the newly planted forest.

25. Allowing natural regeneration

Natural regeneration is a passive method of reforesting a site that entails restricting mowing by posting signs or installing fencing to restrict access and allowing trees to regenerate naturally. This method can take a long time to show results. It may also result in a site covered with invasive species or other undesirable plants, since it is difficult to tell what types of vegetation will grow on a site that is currently being mowed. Good candidate sites for natural regeneration include those with a nearby seed source for the tree species desired at the site, sites with minimal problems with invasive species, and less visible areas of a park, school, or other public land. Natural regeneration is a low-cost, low-effort way to reforest a site.

The most important aspects of using natural regeneration are educating the public and reducing weed competition. No-mow areas should be clearly marked to inform the public or staff of the project and reduce human disturbance (Figure 25). For areas such as public parks or schools, mow a strip just outside the regeneration area to let the public know it is an intentional planting site that is being maintained. Consistent monitoring and removal of invasive plants can also provide a better growing environment for young trees.

Figure 25. Restricting mowing and posting signs will allow forest in this area to regenerate naturally.

- Natural Regeneration: Principles and Practices. 1999. Land for Wildlife Note No. 8. South-east Queensland. www.epa.qld.gov.au/publications/p00254aa.pdf/Natural_regeneration_principles_and_practice.pdf.

26. Actively reforesting public lands and rights-of-way

Actively reforesting public lands throughout a watershed is a more labor-intensive way to create new forests, but allows more control over what types of vegetation become established. Prior to reforesting a site, a detailed assessment should be made of the soils and site conditions to determine what types of trees to plant and to identify any planting constraints. A planting plan should be developed for the site and include the following elements:

- Site preparation (e.g., trash cleanup, removal of invasive plants, soil amendments)
- Species and stock selection (size and species of planting materials)
- Planting zones and layout (where to plant, arrangement and spacing of plants)
- Implementation plan (schedule, equipment and plant materials needed, volunteer recruitment plan)
- Maintenance.

Some general goals of reforestation include maximum canopy coverage, connection with adjacent forested land, a diverse mix of native species, vegetative layers, and habitats. These goals may not all be feasible or desirable for each reforestation site, depending on the current function of the site and existing soil and vegetative conditions. It is also important to maximize the survival of any new plantings by protecting against herbivory and plant competition. To address these unique issues, guidance on planting trees on priority public lands is provided in Chapter 4. More information on planting trees is provided in Part 3 of this manual series.

Reforesting Private Land

Regional GIS analyses of urban areas conducted by American Forests (2001) reveal that about 60% of neighborhoods in the metropolitan areas studied have less than 50% forest canopy cover. The actual rate of tree planting is poorly understood in residential areas. A survey in the Chesapeake Bay watershed indicated that 71% of residents had planted a tree within the last 5 years (CBP, 2002). Lower tree planting rates (about 50%) were reported in urban metropolitan areas such as Baltimore, MD, and Washington, DC.

Reforesting private land may significantly increase forest cover in watersheds, particularly in areas with a high proportion of residential lawns or other privately owned turf. Effective techniques to encourage widespread planting of trees, shrubs, and hedgerows on feasible locations within individual yards or property include these three: developing public education programs that focus on tree planting benefits and techniques, providing financial incentives to plant trees on private property, and promoting public stewardship through the creation and support of citizen action groups that focus on tree planting and preservation. Chapter 4 provides guidance on planting trees in residential lawns to maximize energy savings.

27. Education

Public education is critical in changing public attitudes towards trees. A surprisingly large number of citizens object to having large trees on their property and should be educated about their benefits (GFC, 2001). Public education programs can be designed to convince private landowners and other citizens of the benefits of tree planting and preservation, and to provide guidance on proper techniques for tree planting and maintenance. These programs may include creation of educational workshops, videos, or pamphlets, or distribution of more technical materials such as native plant guidebooks. Education programs are voluntary and are usually geared towards a wide audience.

28. Incentives for tree planting

Financial incentives can encourage private landowners to plant trees on their property. These incentives can take many forms, ranging from free or low cost seedlings or other native tree stock to financial rebates or reduced fees offered by utilities or local governments. Tree seedling giveaways may be coupled with educational programs and may also coincide with nationally recognized days such as Arbor Day or Earth Day (GFC, 2001). Various utilities across the country offer incentives to preserve or plant trees in certain areas of the yard to maximize their cooling benefits. Other communities offer a partial rebate on tree removal permits within 1 year of completed construction. Some examples of incentive programs are available online:

- Slinger,WI, Residential Tree Power Incentive Program: www.slinger-wi-usa.org/utilityprograms.htm
- Tucson, AZ, Electric Power (TEP). Planting Incentives for Residents: http://swenergy.org/programs/arizona/utility.htm
- City of Woodinville, WA, Tree Preservation Incentive Program: www.ci.woodinville.wa.us/documents/Tree%20Incentives%20and%20Regulations.pdf
- City of Hays, KS, Tree Rebate Program: www.haysusa.com/Departments/Parks_Department/Tree_Rebate_Program/tree_rebate_program.html.

29. Stewardship and neighborhood action

Creating or supporting citizen action groups that focus on tree planting and preservation promotes public stewardship of the urban forest. These action groups are typically non-profit, volunteer organizations, and may focus solely on tree planting or may have a wider scope such as watershed stewardship. Members can be drawn from homeowners associations, garden clubs, school groups, or environmental groups. These organizations raise community awareness of the benefits of trees and can also raise funds for tree planting. Citizen tree groups can provide assistance to private landowners on tree planting, particularly when the community does not have a forester or arborist on staff. These groups are vital to community acceptance of trees and can encourage private landowners to plant trees on their property.

- American Forests Global Releaf: www.americanforests.org/global_releaf/
- Trees Atlanta: www.treesatlanta.org
- Iowa State University Extension. Establishing a Community Tree Program. www.extension.iastate.edu/Publications/PM1429a.pdf
- Environmental Law Institute. 2000. Forests for the Bay. Research Report. Washington, DC. www.elistore.org/reports_detail.asp?ID=531&topic=Conservation.

Chapter 4: Planting Guidelines for Priority Reforestation Sites

This chapter provides detailed guidelines for planting trees on these priority reforestation sites in a watershed:

1. Highway rights-of-way
2. Residential lawns
3. Parks
4. School grounds
5. Storm water dry ponds
6. Streams and shorelines
7. Utility corridors
8. Vacant lots.

The guidance is presented in a series of fact sheets that describe the basic reforestation concept and address the following topics:

Pre-Planting Considerations — potential conflicts with planting trees at the site or unique features that drive plant selection and planting procedures. Most of these considerations are addressed under the topics of Species Selection, Site Preparation, Planting Guidance, or Maintenance.

Species Selection — desirable characteristics of species to be planted at the site.

Site Preparation — recommendations for preparing the site for planting.

Planting Guidance — recommendations for stock selection, planting zones, plant spacing, and arrangements and planting methods.

Maintenance — recommendations for tree maintenance.

Potential for Storm Water Treatment — potential for integrating trees and storm water treatment practices in this location.

Further Resources — documents or Web sites referenced in the fact sheet and other relevant resources.

Planting Trees in Highway Rights-of-Way

Description

Larger highways often have fairly large parcels of unused land in the form of cloverleafs and diamonds near interchanges, median strips, and buffers. These rights-of-way can be ideal locations for reforestation because they generally serve no other purpose.

Planting trees along highways can reduce air pollution and stormwater runoff, provide habitat for wildlife such as birds, reduce air temperatures, stabilize the soil, provide a visual screen and buffer from noise and highway fumes, and create a visually pleasing environment for the highway driver.

Pre-Planting Considerations

- ☐ Do highway planting guidelines prohibit or restrict trees?
- ☐ How do I address potential conflicts between trees and utilities?
- ☐ Do I need to use different methods for planting trees on steep slopes?
- ☐ How do I address potential damage to trees from deer?
- ☐ How do I provide unobstructed vehicle recovery areas, clear lines of sight, safe travel surfaces, and access to maintenance structures?
- ☐ Can I make the area more attractive with plantings?
- ☐ How do I address soil conditions such as severe compaction or fill soils?
- ☐ How do I manage invasive plants?
- ☐ How do I address illegal dumping?
- ☐ How do I address exposure of trees to auto emissions, polluted runoff, wind, and drought?

Species Selection

Selecting appropriate tree species is key because it can address most site conditions and is often more efficient than trying to change the site characteristics. Select a diverse mix of hardy, native species that are adapted to soils and site conditions.

Other desirable species characteristics include the following:

- ☐ Tolerates urban stormwater pollutants (oil and grease, metals, chloride)
- ☐ Tolerates air pollution
- ☐ Tolerates poor, highly compacted soils
- ☐ Tolerates drought (rainfall may be the only source of water)
- ☐ Tolerates inundation (if used for stormwater treatment)
- ☐ Provides food, cover, or nesting sites for wildlife
- ☐ Has fall color, spring flowers, or other esthetic benefit.

Site Preparation	☐	Clean up trash and rubble
	☐	Remove invasive plants such as Tree of Heaven (may involve mowing, cutting, and stump treatment)
	☐	Improve soil drainage if needed (e.g., amend with compost, mix soils to a depth of 6 to 18 inches).

General Planting Guidance	☐	Plant trees in groups to provide shared rooting space and allow mowing around trees to control invasive species
	☐	Use groupings of species that provide fall color, flowers, evergreen leaves, and varying heights to create an esthetically pleasing landscape
	☐	Provide gradual transitions between cover types (e.g., soft edges) to benefit wildlife
	☐	Provide setbacks of 17-50 feet between tree planting areas and edge of pavement to reduce limb and leaf fall onto the roadway (Figure 26), prevent trees from falling into the road, allow for vehicle recovery in high speed areas, and prevent icy spots on shaded roadways (Metro, 2002; MD SHA, 2000; NC DOT, no date). Consider ultimate road widening when determining setbacks. Consider planting wildflowers within setback zones.
	☐	Seedlings may be preferable to large nursery stock since they will be watered infrequently (Gilman, 1997)
	☐	Maintain clear line of sight within 25 feet of overhead lights, within 500-1,000 feet of large signs and traffic control devices, and in the area between 2 to 6 feet above roadway elevations. Maintain vertical clearance of 16 feet above roadways (MD SHA, 2000).
	☐	Provide a setback of 5 to 17 feet to allow maintenance access to roadside structures, such as traffic barriers, cabinet devices, noise walls, drainage structures, and utility poles (MD SHA, 2000).
	☐	When planting on slopes, create small earthen berms around trees to help retain moisture. For very steep slopes, use terraces, bioengineering, or consider alternatives to tree planting.

Specific Planting Guidance

Highway Cloverleaves

Provide a setback of 30 to 50 feet between tree planting areas and the edge of pavement, and plant trees or allow natural regeneration in the center of the cloverleaf. The setback ensures adequate sight lines, allows for vehicle recovery and prevents tree branches in roadways (NC DOT, no date).

Highway Buffers

Provide a setback between tree planting areas and the edge of pavement of 20-50 feet for flat areas (or slopes of 3:1 or less) and 17 feet for slopes of 3:1 or steeper (MD SHA, 2000). This setback generally restricts trees in the area between the edge of the pavement and the toe of the slope (swale) to allow adequate sight lines and vehicle recovery and to prevent tree branches in roadways. Create a gradual transition from grasses to trees on cut slopes.

Highway Medians

Medians greater than 25 feet wide can support two rows of trees spaced 20-40 feet apart (GFC, 2002). Provide adequate setbacks to keep utilities clear (if present) and to prevent downed trees or limbs in the roadway. Consider planting large shrubs in median strips if utilities are an issue or if space is limited.

Maintenance

- ☐ Plan for minimal maintenance of trees (watering may not be feasible)
- ☐ Use mulch to retain moisture. Do not mulch deeper than 3 inches or build up mulch around trunks.
- ☐ Mow setback zones and remove any fallen trees or limbs
- ☐ Manage height of volunteer trees to prevent falling during storms
- ☐ Monitor and control invasive species
- ☐ Use integrated pest management to control insects.

Potential for Stormwater Treatment

Trees planted in highway cloverleaves, medians, and buffers can be used to provide treatment of stormwater runoff, since these areas typically already receive polluted runoff from the highway. Cloverleaves are generally large enough to locate most stormwater treatment practices, while median strips and buffers lend themselves to the use of more linear practices such as bioretention, filter strips and swales. Ideas for integrating trees and stormwater treatment in these areas are provided below.

Highway Cloverleaves	Trees can be planted on side slopes and islands in a wooded stormwater wetland (see Part 2 of this manual series for wooded wetland design) constructed in the center of the cloverleaf. Trees should be restricted on embankments, maintenance access areas, and setback zones.
Highway Medians	Trees can be incorporated into swales within highway medians by using tree mounds as check dams (see Part 2 for tree check dam design) or planting trees on side slopes (provided they are not within the setback zone).
Highway Buffers	Trees can be incorporated into a filter strip on flat areas or fill slopes along a highway buffer. The filter strip can either be forested or incorporate multiple vegetative zones that provide a gradual transition from grass to trees.

Further Resources

Maryland State Highway Administration (MDSHA). 2000. Woody Vegetation Management Standards. In *Integrated Vegetation Management Manual for Maryland Highways*.
Online: www.sha.state.md.us

Maryland State Highway Administration (MDSHA) Partnership Planting Program. Contact: Mr. Leroy Jonas, MD SHA Landscape Operations Division C-304, 707 N. Calvert Street, Baltimore, MD 21202.
Online: www.sha.state.md.us/ImprovingOurCommunity/oed/partner.asp

North Carolina Department of Transportation (NCDOT) Division of Highways. *Guidelines for Planting within Highway Right-of-Way*. Raleigh, NC.
Online: www.doh.dot.state.nc.us/operations/dp_chief_eng/roadside/design/PlantingGuid/pdf/PlantingGuidelines.pdf.

Figure 26. Planting trees in highway rights-of-way

Planting Trees on Residential Lawns

Description

Residential lawns are ideal tree planting locations, particularly in former agricultural areas where few trees exist. Planting trees on home lawns can significantly increase the overall tree cover in the watershed since residential lawns typically constitute a large portion of the plantable area. The key is to educate homeowners about the benefits of trees and provide incentives and assistance with tree planting and care so that the number of trees planted is significant.

Trees on residential lawns provide many benefits, including energy cost savings, shade, habitat for wildlife, esthetic value, privacy, and reduction of stormwater runoff. Trees planted next to buildings can reduce summer air conditioning costs by 40% (Akbari and others, 1992).

Pre-Planting Considerations

- ☐ How can I improve the energy efficiency of my home with tree plantings?
- ☐ How can I integrate trees with open turf areas?
- ☐ Can I make the area more attractive with plantings?
- ☐ Is there an opportunity to create habitat for wildlife?
- ☐ How do I manage invasive plants?
- ☐ How do I address potential damage to trees from deer?
- ☐ How do I address potential conflicts between trees and utilities, pavement, and structures?
- ☐ How do I prevent damage to trees from lawnmowers?
- ☐ How do I utilize plantings for visual screening and buffer from wind and noise?

Species Selection

Selecting appropriate tree species is key because it can address most site conditions and is often more efficient than trying to change the site characteristics. Select a diverse mix of hardy, native species that are adapted to soils and site conditions.

Use evergreens for screening and to block winter winds. Other desirable species characteristics include the following:

- ☐ Tolerates drought
- ☐ Tolerates urban pollutants
- ☐ Tolerates poor or compacted soils
- ☐ Provides food, cover, or nesting sites for wildlife.

Site Preparation	☐	Remove invasive plants such as multiflora rose (may include mowing, cutting, or stump treatment)
	☐	Improve soil drainage if needed (e.g., amend with compost, mix soils to a depth of 6 to 18 inches).
General Planting Guidance	☐	Plant a tree to shade the area over your air conditioner and reduce energy use (Figure 27).
	☐	Plant deciduous trees on the west, south, and east sides of the building to block the summer sun (Figure 28).
	☐	Plant a row of evergreens on the north side of the building to block cold winter winds.
	☐	Provide adequate setbacks between trees and buildings, utilities, and pavement.
	☐	Cluster trees to provide shared rooting space and an even canopy, using species that grow at about the same rate so they don't shade each other out. Use mulch rings and mow around the clusters.
	☐	Use trees to delineate borders or provide visual screens.
	☐	Use trees to provide a buffer from noise. To be effective, the buffer should be dense, tall, and wide, and planted close to the source of the noise. Contiguous rows of trees in widths of 16 feet or more are especially effective (TreesAtlanta, no date).
Maintenance	☐	Plan for low maintenance of trees (frequent watering may not be feasible)
	☐	Use mulch to retain moisture and protect trees from mowers and foot traffic
	☐	Monitor and control invasive plants
	☐	Prune trees where necessary to maintain visibility and safety.
Potential for Stormwater Treatment		Trees on residential lawns are not likely to have high potential for stormwater treatment since most homeowners are not responsible for providing treatment of runoff from their property. In cases where homeowners are responsible for swales located on their properties, alternating side slope plantings or tree check dams could be used. (See Part 2 of this manual series for tree check dam design.)

Further Resources

Akbari, H., Davis, S., Dorsano, S., Huang, J. and S. Winnett. 1992. *Cooling Our Communities. A Guidebook on Tree Planting and Light-Colored Surfacing*. U.S. EPA. Lawrence Berkeley Laboratory Report LBL-31587.

Planting Trees Around Your Home. Fact Sheet available on The Forest Where We Live Web site: www.lpb.org/programs/forest/plantguide.html

Trees Atlanta. No Date. *Facts*. Website: www.treesatlanta.org/facts.html

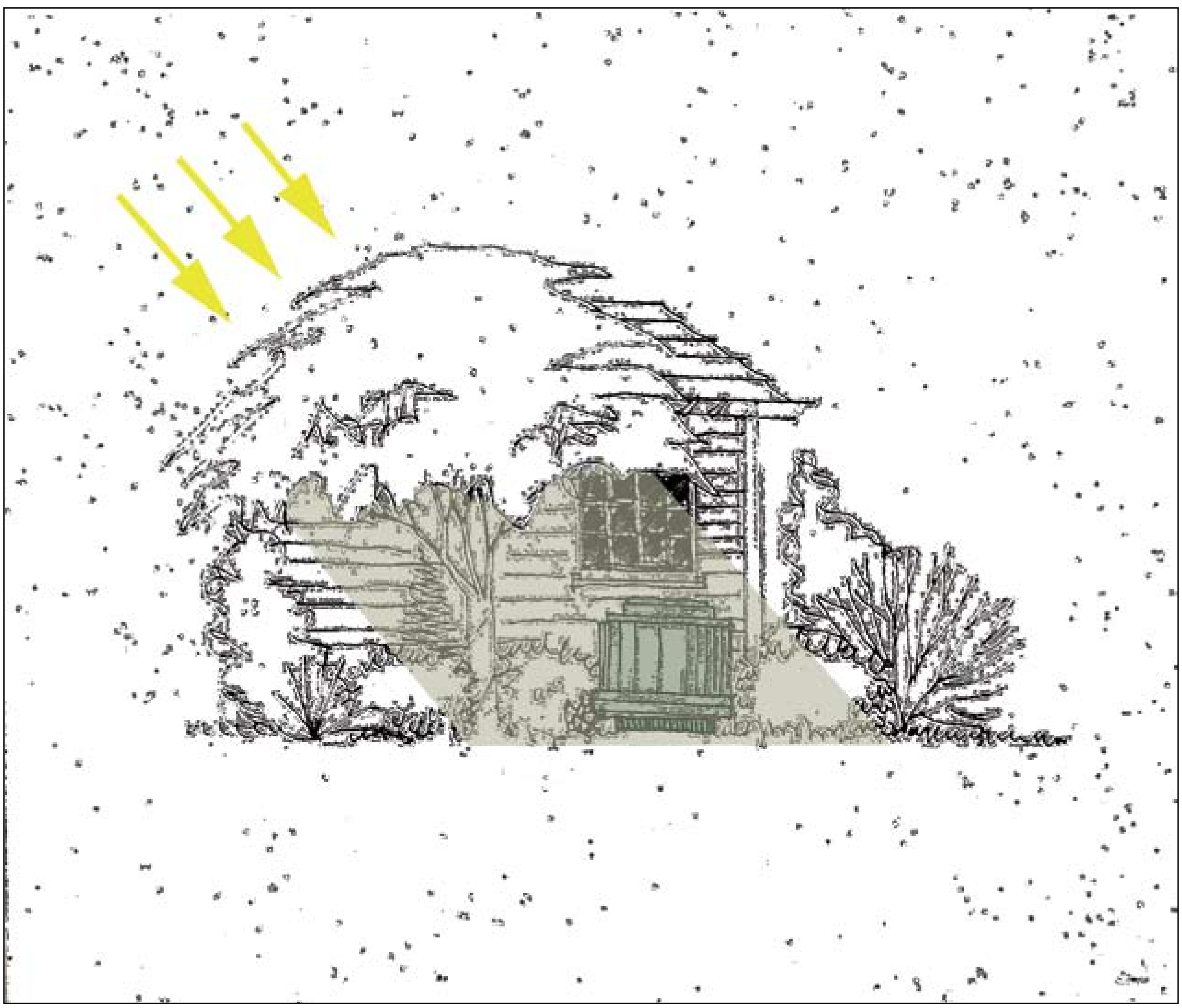


Figure 27. Strategically placed trees shade the air conditioning unit, providing energy savings

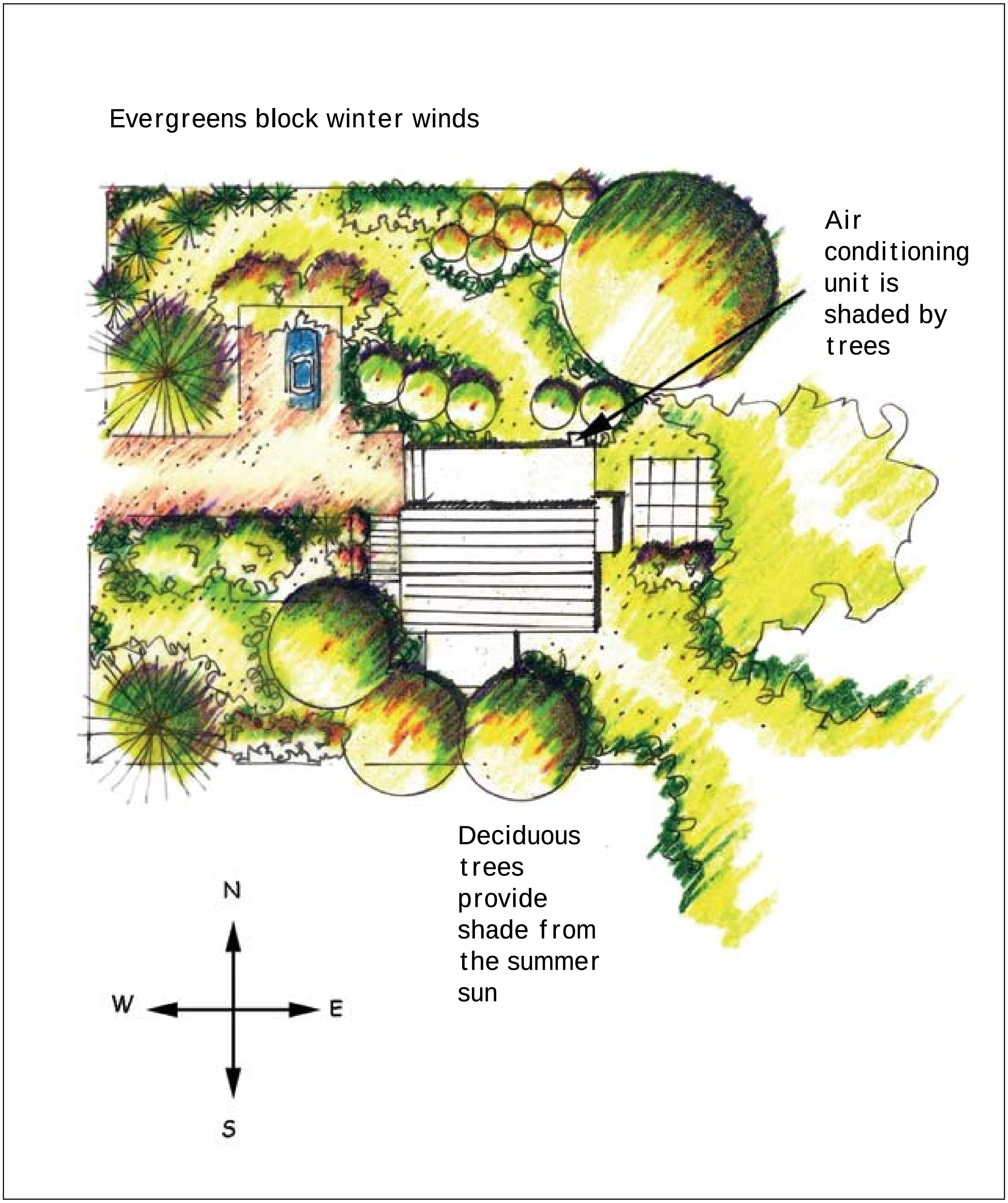


Figure 28. Planting trees on residential lawns

Planting Trees in Parks

Description

Parks provide ideal locations for reforestation since they often have large underutilized open areas for planting trees and are publicly owned. Benefits of planting trees in parks include wildlife habitat, shading, soil stabilization, reduced storm water runoff, and improved recreational opportunities, quality of life, and air quality.

Pre-Planting Considerations

- ☐ How do I address concerns about vandalism, safety, liability, and visibility?
- ☐ How do I integrate trees with recreational uses, such as ballfields and trails?
- ☐ How do I prevent soils in the planting area from being compacted by foot traffic?
- ☐ Can I make the area more attractive with plantings?
- ☐ Is there an opportunity to create habitat for wildlife?
- ☐ How do I address illegal dumping?
- ☐ How do I manage invasive plants?
- ☐ How do I address potential damage to trees from deer?
- ☐ How do I address potential conflicts between trees and street lights, utilities, and pavement?
- ☐ How do I prevent damage to trees from lawnmowers?

Species Selection

Selecting appropriate tree species is key because it can address most site conditions and is often more efficient than trying to change the site characteristics. Select a diverse mix of hardy, native species that are adapted to soils and site conditions.

Select species with similar growth rates when planting in groves (so they do not shade each other out). Limit use of understory trees and shrubs in areas where visibility and safety are important. Other desirable species characteristics include the following:

- ☐ Tolerates drought
- ☐ Tolerates urban pollutants
- ☐ Tolerates poor or compacted soils
- ☐ Tolerates inundation (if used for stormwater treatment)
- ☐ Large shade tree with a single leader that can be limbed up to 6 feet
- ☐ Provides food, cover, or nesting sites for wildlife
- ☐ Reflects local character and culture.

Site Preparation	☐	Clean up trash or other illegally dumped material
	☐	Remove invasive plants such as multiflora rose (may include mowing, cutting, or stump treatment)
	☐	Improve soil drainage if needed (e.g., amend with compost, mix soils to a depth of 6 to 18 inches).
General Planting Guidance	☐	Trees can be incorporated when developing landscaping plans for new parks. Select planting areas that are adjacent to existing forest or other natural areas or protect natural features such as streams (Figure 29).
	☐	Plant to provide shade around bleachers and ballfields. Use trees to create screens and boundaries between different areas.
	☐	Allow natural regeneration in less visible areas. Mow a strip outside the regeneration area and clearly mark with signs to educate the public and let them know it is intentional.
	☐	Plant street trees or specimen trees around the perimeter of the site at a spacing of 30 to 45 feet on center, to allow mowing in between for invasive species control.
	☐	Cluster trees to provide shared rooting space and an even canopy, using species that grow at about the same rate so they don't shade each other out. Use mulch rings and mow around the clusters.
	☐	Post signs to identify intentional plantings.
	☐	Use small plant materials (e.g., seedlings, whips) where foot traffic is not an issue and larger stock elsewhere. Mix stock where both understory and canopy trees will be planted (smaller understory stock and larger canopy stock), or in tree clusters to protect whips (plant large stock around perimeter and whips in center).
	☐	Where potential liability due to tree climbing is a concern, prune mature trees to the shoulder height of an adult and plant low shrubs or ground cover at tree base.
	☐	Use tree cages or benches to protect trees from vandalism, or plant species with inconspicuous bark or with thorns to discourage vandalism (Palone and Todd, 1998).
	☐	Plant only low growing herbaceous vegetation in areas where visibility is important for safety reasons. Do not plant evergreens, understory, or ornamental trees or shrubs in these areas. This includes within 10 feet of the centerline of trails, near seating areas, intersections and approaches to trails. Prune or limb trees in these areas up to 8 feet to maintain visibility (TCF, 1993). Provide trail breaks in case of emergency (TCF, 1993).
	☐	Plant trees where traffic is minimal, such as along fencelines. Protect trees and their critical root zone (generally a 25-foot radius) from foot traffic (soil compaction) by using recycled rubber or by directing foot traffic to certain areas using low metal fences, curbs, posts and chains, or porous pavers (Patterson, 1995)

Maintenance

- ☐ Plan for low maintenance of trees (frequent watering may not be feasible)
- ☐ Use mulch to retain moisture and protect trees from mowers and foot traffic. Do not mulch deeper than 3 inches or build up mulch around trunk.
- ☐ Mow around tree clusters, in setback areas, and in other areas that require access, safety, and visibility
- ☐ Monitor and control invasive plants
- ☐ Prune trees where necessary to maintain visibility and safety.

Potential for Stormwater Treatment

Trees planted in parks may be used to provide treatment of stormwater runoff since these areas often have large open areas available for stormwater treatment practices. Depending on available space, site conditions, and runoff volume, the following types of practices may be used: stormwater wetlands, bioretention and bioinfiltration, swales and filter strips. Trees can be incorporated into all of these treatment practices, and design and planting guidance for each is presented in Part 2 of this manual series.

Further Resources

Northeastern Illinois Planning Commission (NIPC). 1997. *Natural Landscaping for Public Officials*. Chicago, IL.

Parks and People Foundation. Online: www.parksandpeople.org

The Conservation Fund (TCF). 1993. *Greenways: A Guide to Planning, Design and Development*. Island Press. Washington, DC.

Figure 29. Planting trees in parks

Planting Trees on School Grounds

Description

Schools provide ideal locations for reforestation since they are publicly owned and often have large underutilized open areas for planting trees. Benefits of planting trees on school grounds include wildlife habitat, shading, soil stabilization, improved recreational opportunities and quality of life, educational opportunities, improved air quality, and reduced stormwater runoff.

Pre-Planting Considerations

- ☐ How do I address concerns about vandalism, safety, liability and visibility?
- ☐ Is there an opportunity to provide educational value?
- ☐ How do I integrate trees with recreational uses such as ballfields and trails?
- ☐ How do I prevent soils in the planting area from being compacted by foot traffic?
- ☐ Is there an opportunity to create habitat for wildlife?
- ☐ How do I address illegal dumping?
- ☐ How do I manage invasive plants?
- ☐ How do I address potential damage to trees from deer?
- ☐ How do I address potential conflicts between trees and street lights, utilities, and pavement?

Species Selection

Selecting appropriate tree species is key because it can address most site conditions and is often more efficient than trying to change the site characteristics. Select a diverse mix of hardy, native species that are adapted to soils and site conditions.

Select species with similar growth rates when planting in groves (so they do not shade each other out). Limit use of understory trees and shrubs in areas where visibility and safety are important.

Other desirable species characteristics include the following:

- ☐ Tolerates drought
- ☐ Tolerates urban pollutants
- ☐ Tolerates poor or compacted soils
- ☐ Tolerates inundation (if used for stormwater treatment)
- ☐ Large shade trees with a single leader that can be limbed up to 6 feet
- ☐ Provides food, cover, or nesting sites for birds, squirrels, and other wildlife
- ☐ Reflects local character and culture.

Site Preparation

- ☐ Clean up trash or other illegally dumped material
- ☐ Remove invasive plants such as multiflora rose (may include mowing, cutting, or stump treatment)
- ☐ Improve soil drainage if needed (e.g., amend with compost, mix soils to a depth of 6 to 18 inches).

General Planting Guidance

- ☐ Trees can be incorporated when developing landscaping plans for new schools. Select planting areas that are adjacent to existing forest or other natural areas or protect natural features such as streams.
- ☐ Plant to provide shade around bleachers and ballfields (Figure 30). Use trees to create screen and boundaries between different areas.
- ☐ Plant street trees or specimen trees around the perimeter of the site at spacing of 30 to 45 feet on center to allow mowing in between for invasive control.
- ☐ Cluster trees to provide shared rooting space and an even canopy, using species that grow at about the same rate so they don't shade each other out. Do not include turf in tree clusters. Instead, use mulch rings and mow around the clusters.
- ☐ Post signs to identify intentional plantings
- ☐ Use small plant materials (e.g., seedlings, whips) where foot traffic is not an issue and larger stock elsewhere. Mix stock where both understory and canopy trees will be planted (e.g., use small understory stock and large canopy stock), or in tree clusters to protect seedlings (e.g., plant large stock around perimeter and seedlings in center).
- ☐ Where potential liability from tree climbing is a concern, prune mature trees to the shoulder height of an adult and plant low shrubs or ground cover at tree base.
- ☐ Plant only low growing herbaceous vegetation in areas where visibility is important for safety reasons or limb trees up to 8 feet in these areas to maintain visibility.
- ☐ Plant trees where traffic is minimal, such as along fencelines. Protect trees and their critical root zone (generally a 25-foot radius) from foot traffic (soil compaction) by using recycled rubber or by directing foot traffic to certain areas using low metal fences, curbs, posts and chains, or porous pavers (Patterson, 1995)

Maintenance	☐	Plan for low maintenance of trees (frequent watering may not be feasible)
	☐	Use mulch to retain moisture and protect trees from mowers and foot traffic. Do not mulch deeper than 3 inches or build up mulch around tree trunks.
	☐	Mow around tree clusters, in setback areas, and other areas to maintain access, safety, and visibility
	☐	Monitor and control invasive plants
	☐	Prune trees where necessary to maintain visibility and safety.

Potential for Stormwater Treatment

Trees planted at schools may be used to provide treatment of stormwater runoff since school grounds often have large open areas available for stormwater treatment practices. Depending on available space, site conditions, and runoff volume, the following types of practices may be used: stormwater wetlands, bioretention and bioinfiltration, swales, and filter strips. Trees can be incorporated into all of these treatment practices, and design guidance for each is provided in Part 2 of this manual series. Safety concerns may limit the use of stormwater wetlands or other practices with standing or deep water.

Further Resources

Martin, D., D. Lucas, S. Titman and S. Hayward. 1996. *The Challenge of the Urban School Site.* Green Brick Road. 800-471-3638. $27 Cdn.

Maryland State Department of Education. 1999. *Conserving and Enhancing the Natural Environment: A Guide for Planning, Design, Construction, and Maintenance on New and Existing School Sites*. Baltimore, MD.

National Wildlife Federation (NWF). 2001. *Schoolyard Habitats: A How To Guide for K-12 School Communities*. www./nwf.org/bookstore

Northeastern Illinois Planning Commission (NIPC). 1997. *Natural Landscaping for Public Officials*. Chicago, IL.

U.S. Fish and Wildlife Service (USFWS). Schoolyard Habitat Program. Online: www.fws.gov/r5cbfo/schoolyd.htm

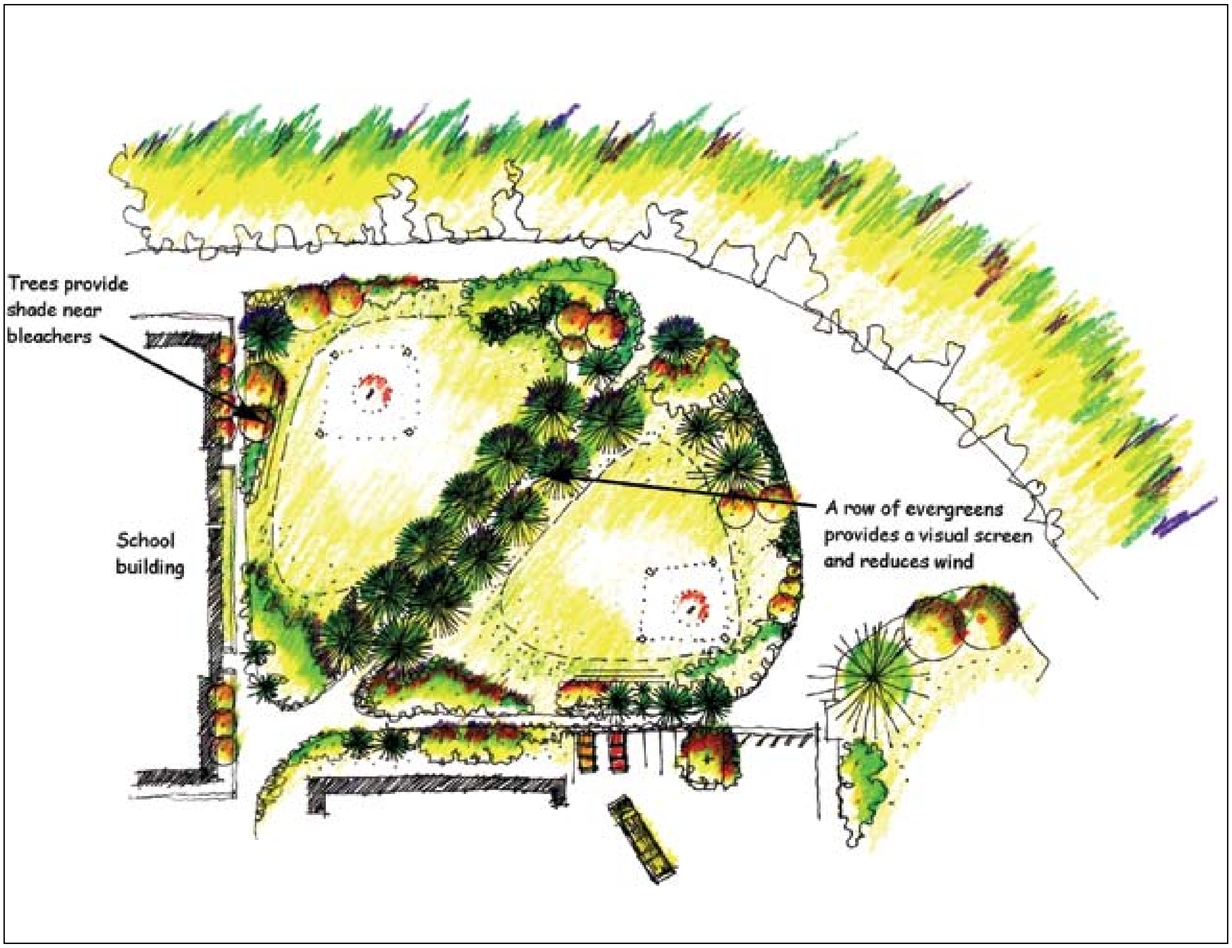


Figure 30. Planting trees on school grounds

Planting Trees in Stormwater Treatment Dry Ponds

Description

In urban areas, lands devoted to treating urban stormwater runoff and septic effluent can comprise up to 3% of the total land area in the watershed (CWP, 2000b). Stormwater dry ponds are one such type of land and are typically maintained as turf. Planting trees in existing dry ponds increases their esthetic value in the community (particularly if they are highly visible) and may increase pollutant removal. Few engineering constraints exist with planting trees in dry ponds as they may be planted anywhere within the practice.

Pre-Planting Considerations

- ☐ Can I make the pond more attractive with plantings?
- ☐ How do I prevent damage to trees from lawnmowers?
- ☐ How do I manage invasive plants?
- ☐ How do I address potential damage to trees from deer?
- ☐ How do I address soil conditions such as severe compaction and fluctuations in soil moisture?

Species Selection

Selecting appropriate tree species is key because it can address most site conditions and is often more efficient than trying to change the site characteristics. Select a diverse mix of hardy, native species that are adapted to soils and site conditions.

Other desirable species characteristics include the following:

- ☐ Tolerates drought
- ☐ Tolerates inundation
- ☐ Tolerates urban pollutants (sediment, nutrients, metals, bacteria, pesticides)
- ☐ Tolerates poor or compacted soils
- ☐ Has fall color, spring flowers, or other esthetic benefit.

Site Preparation

- ☐ Remove invasive plants such as multiflora rose (may include mowing or cutting)
- ☐ Improve soil drainage if needed (e.g., amend with compost, mix soils to a depth of 6 to 18 inches).

General Planting Guidance

- ☐ Plant trees in groups to provide shared rooting space and allow mowing around trees to control invasive species
- ☐ Use groupings of species that provide fall color, flowers, evergreen leaves, and varying heights to create an esthetically pleasing landscape (Figure 31)
- ☐ When planting on pond side slopes, create small earthen berms around trees to help retain moisture.
- ☐ Where soils are compacted and amendments are not possible, provide adequate soil volume in planting hole.

Maintenance

- ☐ Plan for little maintenance of trees (regular watering may not be feasible)
- ☐ Mow around tree clusters to control invasive plants. Do not mulch deeper than 3 inches or build up mulch around trunks.
- ☐ Use mulch to retain moisture

Potential for Stormwater Treatment

A dry extended detention pond provides treatment of stormwater primarily through settling. After storms, stored runoff is gradually released over a period of 1 to 3 days, allowing an opportunity for pollutants to settle out to the floor of the pond. Trees may increase the pollutant removal ability of a dry pond through nutrient uptake.

Further Resources

Shaw, D. and R. Schmidt. 2003. *Plants for Stormwater Design*. Minnesota Pollution Control Agency. Saint Paul, MN.

Figure 31. Planting trees in storm water treatment dry ponds

Planting Trees Along Streams and Shorelines

Description

Trees planted along streams and shorelines provide many benefits, including regulation of stream temperature, stabilization of streambanks, enhancement of habitat for both aquatic and terrestrial species, and pollutant removal. The urban stream corridor is an ideal place for reforestation because of these many benefits, and because it often includes land that cannot otherwise be developed due to its location within the floodplain or inclusion of steep ravines. Three typical urban stream corridor scenarios and related reforestation goals are described below.

Natural forested stream buffer	Provides habitat for wildlife, stream shading, pollutant removal, large woody debris, leaf litter, bank stabilization
Landscaped buffer (residential backyards, parks, and other managed spaces)	Provides access to stream, passive recreation and water views for residents and park users, stream shading and bank stabilization, some pollutant removal
Highly modified buffer (ultra-urban channelized stream)	Provides beautification opportunities even though the forestable area may be limited. Daylighting or removal of impervious cover may increase tree planting opportunities.

Pre-Planting Considerations

- ☐ Do floodway regulations prohibit trees?
- ☐ How do I manage invasive plants?
- ☐ How do I address potential damage to trees from deer?
- ☐ How do I address potential conflicts between trees and utilities?
- ☐ Do I need to use different methods for planting trees on steep slopes?
- ☐ How do I address illegal dumping?
- ☐ Is there an opportunity to create habitat for wildlife?
- ☐ How do I address concerns about safety, nuisance rodents, weeds, esthetics, and wildlife?
- ☐ How do I address urban stream impacts, such as lowered baseflow?

Species Selection	Selecting appropriate tree species is key because it can address most site conditions and is often more efficient than trying to change the site characteristics. Select a diverse mix of hardy, native species that are adapted to soils and site conditions. Use large trees for small streams with shallow banks, and shrubs or small trees to provide stability for steep banks or larger streams with high flows. Mix canopy and understory species to create vertical structure. Other desirable species characteristics include the following: ☐ Tolerates inundation (although upland species may do well where the riparian zone is drying out) ☐ Wide, spreading canopy ☐ Provides food, cover, or nesting sites for wildlife.	
Site Preparation	☐ Remove any trash or other illegally dumped material ☐ Remove invasive plants such as multiflora rose (may include mowing, cutting, or spraying with aquatic-use herbicide) ☐ Improve soil drainage if needed (e.g., amend with compost, mix soils to a depth of 6 to 18 inches).	
General Planting Guidance	☐ Use three-zone buffer design (Welsch, 1991) with the following zones: streamside, middle, and outer. Each zone should have different vegetative targets, widths, and allowable uses that are progressively more restrictive as you move towards the stream (Figure 32). ☐ Focus on providing a forested strip immediately adjacent to the stream if land use limits reforestation of the entire site (Figure 33) ☐ Select a mix of stock so trees do not all die at the same time. Use larger trees next to the stream and seedlings elsewhere. Bare root stock may be easier for volunteers to plant and require less water. ☐ Random spacing is preferred but can make survival counts difficult ☐ If mowing between trees is necessary, provide enough space for mowers to avoid damaging trees.	
Maintenance	☐ Design for little or no maintenance (watering may not be feasible) ☐ Use mulch to retain moisture. Do not mulch deeper than 3 inches or build up mulch around trunks. ☐ Use tree shelters to protect seedlings from deer ☐ Continually monitor for and remove invasive species (mowing in between trees may be necessary).	

Potential for Stormwater Treatment

If stormwater runoff crosses the stream buffer in a pipe, potential for stormwater treatment is low. Runoff from adjacent land uses may be directed to the buffer as sheetflow for stormwater treatment. Linear stormwater treatment practices such as filter strips and bioretention may work best here, although depending on space available, stormwater wetlands could also be used. Guidance for incorporating trees into these practices is provided in Part 2 of this manual series.

Further Resources

Alliance for the Chesapeake Bay (ACB). 2002. *Pennsylvania Stream ReLeaf Forest Buffer Toolkit*. Pennsylvania Department of Environmental Protection, Bureau of Watershed Conservation.
www.dep.state.pa.us/dep/deputate/watermgt/wc/subjects/StreamReLeaf

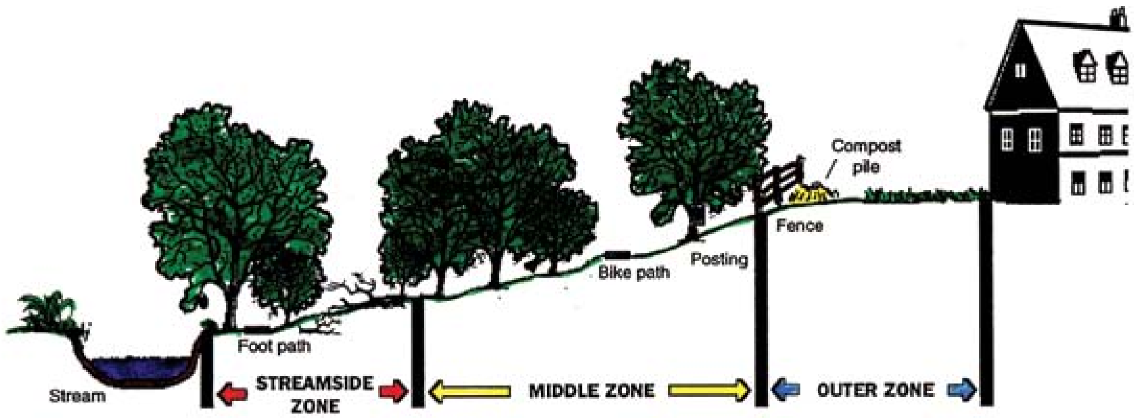
Native Plants by Region for Riparian Forest Buffers:
www.rce.rutgers.edu/njriparianforestbuffers/nativeALL.htm

Palone, R. and A. Todd. 1998. *Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers*. USDA Forest Service, Northeastern Area State and Private Forestry.
www.chesapeakebay.net/pubs/subcommittee/nsc/forest/handbook.htm

Schueler, T. 1995. *Site Planning for Urban Stream Protection*. Center for Watershed Protection and the Metropolitan Washington Council of Governments.

Standard for Riparian Forest Buffer from the New Jersey BMP Manual:
www.state.nj.us/dep/watershedmgt/DOCS/BMP_DOCS/chapter5_reparian_buffer.PDF

Welsch, D. 1991. *Riparian Forest Buffers – Function and Design for Protection and Enhancement of Water Resources*. 28 pp. USDA Forest Service NA-PR-07-91. Radnor, PA. www.na.fs.fed.us/spfo/pubs/n_resources/buffer/cover.htm



CHARACTERISTICS	STREAMSIDE ZONE	MIDDLE ZONE	OUTER ZONE
FUNCTION	Protect the physical integrity of the stream ecosystem	Provide distance between upland development and streamside zone	Prevent encroachment and filter backyard runoff
WIDTH	Min. 25 feet, plus wetlands and critical habitats	50 to 100 feet, depending on stream order, slope, and 100 year floodplain	25 foot minimum setback to structures
VEGETATIVE TARGET	Undisturbed mature forest. Reforest if grass	Managed forest, some clearing allowable	Forest encouraged, but usually turfgrass
ALLOWABLE USES	***Very Restricted*** e.g., flood control, utility right of ways, footpaths, etc.	***Restricted*** e.g., some recreational uses, some stormwater BMPs, bike paths, tree removal by permit	***Unrestricted*** e.g., residential uses including lawn, garden, compost, yard wastes, most stormwater BMPs

Figure 32. The three-zone stream buffer system (Source: Schueler, 1995, p. 111)

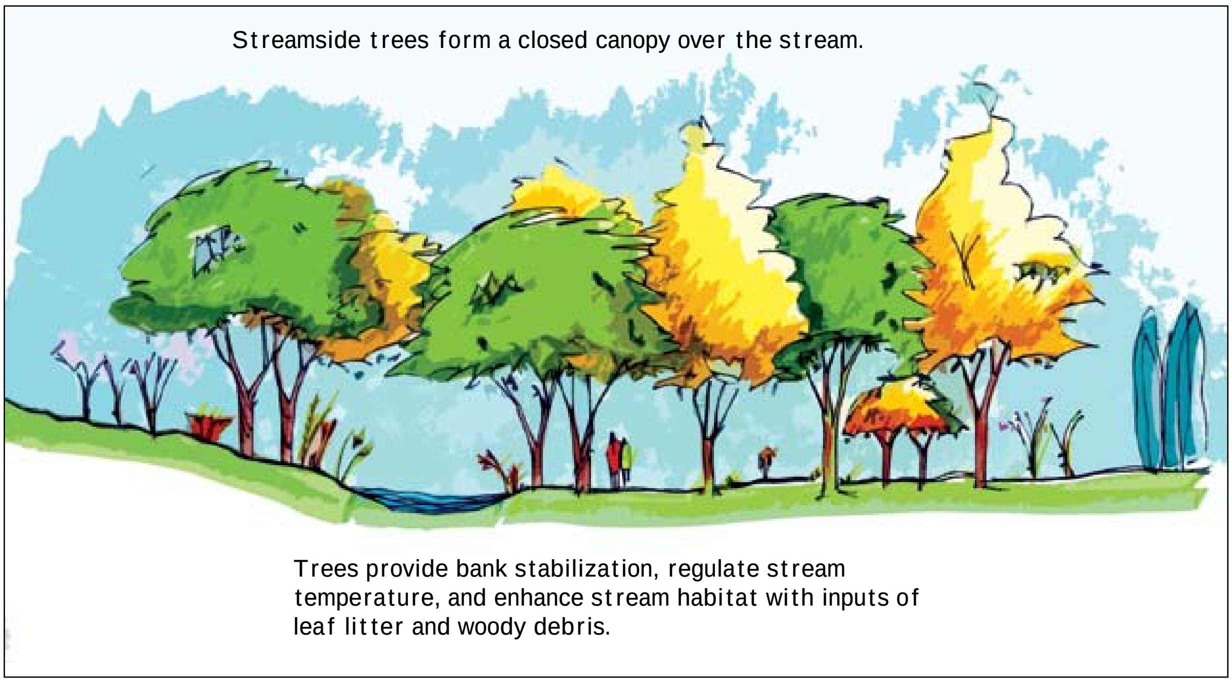


Figure 33. Planting trees along streams and shorelines

Planting Trees in Utility Corridors

Description

Utility corridors are linear features that contain power and gas transmission lines. These corridors can be up to 150 feet wide and contain above- and below-ground utility lines. Most utility corridors are privately owned; therefore, their reforestation potential will depend on the vegetation management policy of the utility company. Planting trees in utility corridors can create wildlife habitat corridors, and improves air quality, stabilizes soil, reduces runoff, and reduces air temperature.

Pre-Planting Considerations

- ☐ Do I have permission of utility company to plant trees?
- ☐ How do I address potential conflicts between trees and utilities?
- ☐ How do I manage invasive plants?
- ☐ Is there an opportunity to create habitat for wildlife?
- ☐ How do I address potential damage to trees from deer?
- ☐ How do I provide maintenance access to utility structures and visibility for fly-over inspections?
- ☐ How do I address security concerns?

Species Selection

Selecting appropriate tree species is key because it can address most site conditions and is often more efficient than trying to change the site characteristics. Select a diverse mix of hardy, native species that are adapted to soils and site conditions.
Other desirable species characteristics include the following:

- ☐ Is a shrub or small tree less than 10 feet high when mature
- ☐ Provides food, cover, or nesting sites for desired wildlife
- ☐ Tolerates drought (rainfall may be the only source of water)
- ☐ Tolerates inundation (if used for stormwater treatment)
- ☐ Tolerates urban pollutants and poor soils.

Site Preparation

- ☐ Clean up trash and other illegally dumped material
- ☐ Remove invasive or unwanted plants such as multiflora rose (may include mowing, cutting, or spraying with herbicide approved for aquatic use)
- ☐ Improve soil drainage if needed (e.g., amend with compost, mix soils to a depth of 6 to 18 inches).

General Planting Guidance	☐	Do not plant trees or shrubs along gas transmission lines since canopy limits ability to inspect lines for leaks. Establish meadow vegetation instead.
	☐	Promote the growth of low-growing, shrub or scrub plant communities within electric transmission corridors. Do not plant trees greater than 10 feet mature height within 75 feet of electric transmission lines (Head and others, 2001). Instead, plant small trees, shrubs, or meadow vegetation (Figure 34).
	☐	Create soft edges between the utility corridor and adjacent vegetation by providing a gradual transition from herbaceous vegetation to shrubs to trees as you move away from the power lines. These edges provide a diversity of habitat for wildlife.
	☐	Provide setbacks from utility structures to provide maintenance access.
Maintenance	☐	Plan for minimal maintenance of trees and shrubs (watering may not be feasible)
	☐	Use mulch to retain moisture. Do not mulch deeper than 3 inches or build up mulch around trunks.
	☐	Monitor and control invasive plants
	☐	Use Integrated Vegetation Management (IVM) to maintain low-growing vegetative community (less than 10 feet in height). This includes mowing, hand removal of vegetation, and selective spraying of individual trees in early growing stage (Genua, 2000).
	☐	Where utility corridor crosses the stream, do not mow within 50 feet and use only herbicides approved for aquatic use.
Potential for Stormwater Treatment		Trees and shrubs planted in utility corridors may be used to provide treatment of stormwater runoff from nearby impervious surfaces. Linear stormwater treatment practices such as swales, bioretention, and filter strips are most applicable in a utility corridor. Perhaps the most appropriate use of trees for stormwater treatment in a utility corridor is a filter strip incorporating multiple vegetative zones to provide a gradual transition from herbaceous vegetation to trees. Design guidance for these practices is provide in Part 2 of this manual series.

Further Resources

Genua, S. M. 2000. *Converting Power Easements into Butterfly Habitats*. Potomac Electric Power Company (PEPCO). Online: www.butterflybreeders.org/pages/powerease_sg.html

Wildlife Habitat Council. Online: www.wildlifehc.org/spotlight/index.cfm

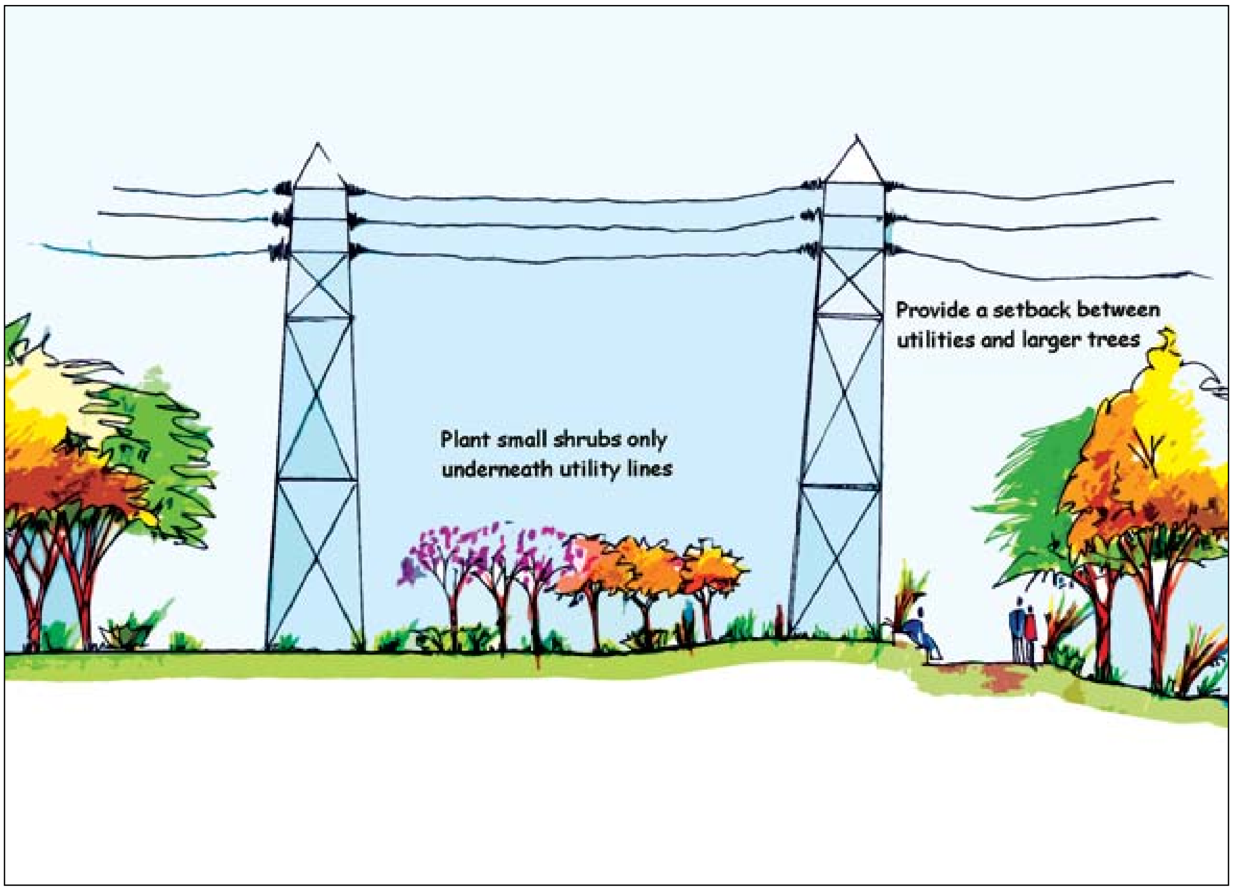


Figure 34. Planting trees in utility corridors

Planting Trees in Vacant Lots

Description	Many older urban areas have numerous vacant lots that cumulatively can increase watershed forest cover through reforestation. Planting trees in vacant lots can also provide much needed community green space for local residents. Other benefits of planting trees in vacant lots include wildlife habitat, shading, soil stabilization, improved air quality, and reduced stormwater runoff.

Pre-Planting Considerations

- ☐ Do I have landowner permission to plant trees?
- ☐ How do I address concerns about vandalism, crime, vagrants, visibility, and safety?
- ☐ Is there an opportunity to create wildlife habitat?
- ☐ How do I address illegal dumping?
- ☐ How do I manage invasive plants?
- ☐ How do I address potential damage to trees from deer?
- ☐ How do I address potential conflicts between trees and street lights, utilities, and pavement?
- ☐ How do I address soil conditions such as severe compaction, building rubble, and potential contamination?
- ☐ Is there an opportunity to provide a visual identity for the community?

Species Selection

Selecting appropriate tree species is key because it can address most site conditions and is often more efficient than trying to change the site characteristics. Select a diverse mix of hardy, native species that are adapted to soils and site conditions.

Other desirable species characteristics include the following:

- ☐ Tolerates drought
- ☐ Tolerates urban pollutants (lead)
- ☐ Tolerates poorly drained, compacted soils
- ☐ Tolerates alkaline soils
- ☐ Tolerates inundation (if used for stormwater treatment)
- ☐ Fast-growing
- ☐ Not an ornamental
- ☐ Provides food, cover, or nesting sites for birds, squirrels and other wildlife.

Site Preparation	☐	Clean up trash, rubble, or other illegally dumped material
	☐	Remove invasive plants such as multiflora rose (may include mowing, cutting, or stump treatment)
	☐	Bring in new soils or improve existing soil drainage (e.g., amend with compost, mix soils to a depth of 6 to 18 inches).
General Planting Guidance	☐	A defined edge shows the lot is being cared for. Install a border of street trees, fencing, or bollards around the perimeter to create this defined edge (Figure 35). Plant street trees or specimen trees around the perimeter of the site at spacing of 30-45 feet on center to allow mowing in between for invasive control.
	☐	Provide clear sight lines around the site perimeter for pedestrian safety. This may involve mowing, limbing trees up to 6 feet, or planting only very low growing vegetation.
	☐	Post signs, incorporate design elements into the site, and consider curb appeal to provide a visual identity for the community.
	☐	Use trees to provide shade or screens where appropriate.
	☐	Cluster trees in center of lot to provide shared rooting space and an even canopy, using species that grow at about the same rate so they do not shade each other out. Do not include turf in tree clusters. Instead, use mulch rings and mow around the clusters.
	☐	Use small plant materials (e.g., seedlings, whips) where foot traffic is not an issue and larger stock elsewhere. Mix stock where both understory and canopy trees will be planted (e.g., use small understory stock and large canopy stock), or in tree clusters to protect seedlings (e.g., plant large stock around perimeter and seedlings in center).
	☐	Install lighting and post signs to prevent illegal dumping and vandalism (Figure 36).
	☐	Use tree cages or benches to protect trees from vandalism. Or plant species with inconspicuous bark or thorns to discourage vandalism (Palone and Todd, 1998).
Maintenance	☐	Plan for low maintenance of trees (frequent watering may not be feasible)
	☐	Use mulch to retain moisture and protect trees from mowers and foot traffic. Do not mulch deeper than 3 inches or build up mulch around trunks.
	☐	Mow around tree clusters, in setback areas, and other areas to maintain access, safety, and visibility
	☐	Monitor and control invasive plants
	☐	Prune trees where necessary to maintain visibility and safety.

Potential for Stormwater Treatment

Trees planted in vacant lots may be used to provide treatment of stormwater runoff if soils and the water table allow. Vacant lots may have significant area available for stormwater treatment practices, but if soils are highly disturbed and poorly drained, or water table is close to surface, treatment may be limited (or underdrain may be needed) to prevent soggy basements next door or standing water. Depending on available space, site conditions and runoff volume, the following types of practices may be used: stormwater wetlands, bioretention and bioinfiltration, swales, and filter strips. Trees can be incorporated into all of these treatment practices.

Further Resources

Palone, R. and A. Todd. 1998. *Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers*. USDA Forest Service, Northeastern Area State and Private Forestry.
www.chesapeakebay.net/pubs/subcommittee/nsc/forest/handbook.htm

Pennsylvania Horticultural Society. 2002. *Reclaiming Vacant Lots*. Philadelphia, PA.

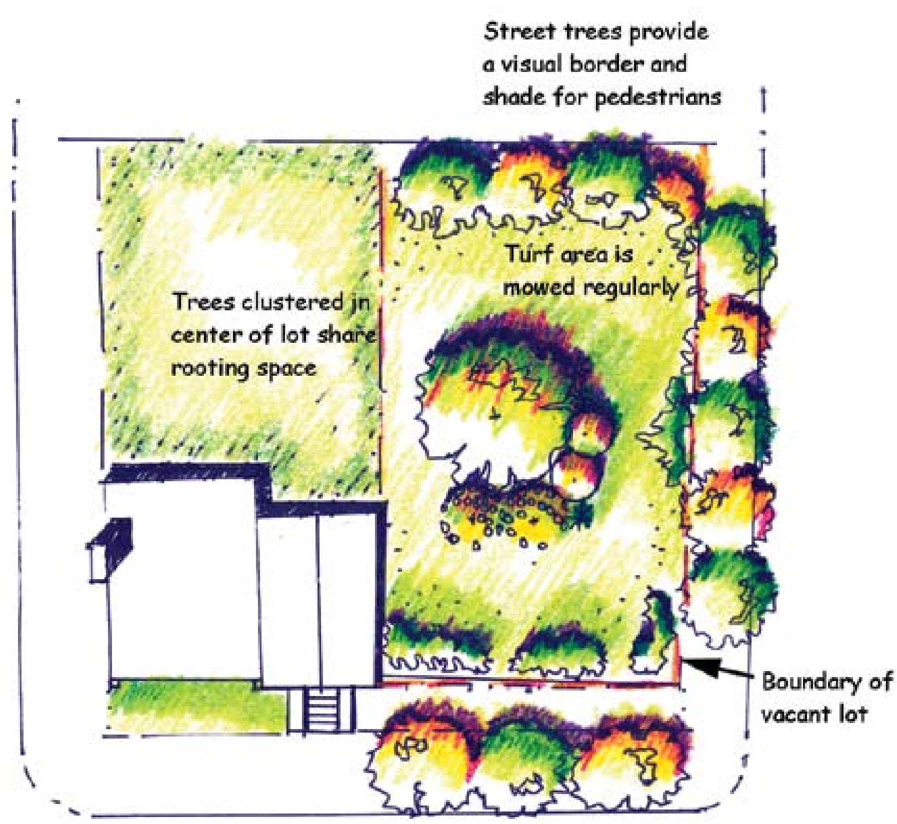


Figure 35. Planting trees in vacant lots—plan view

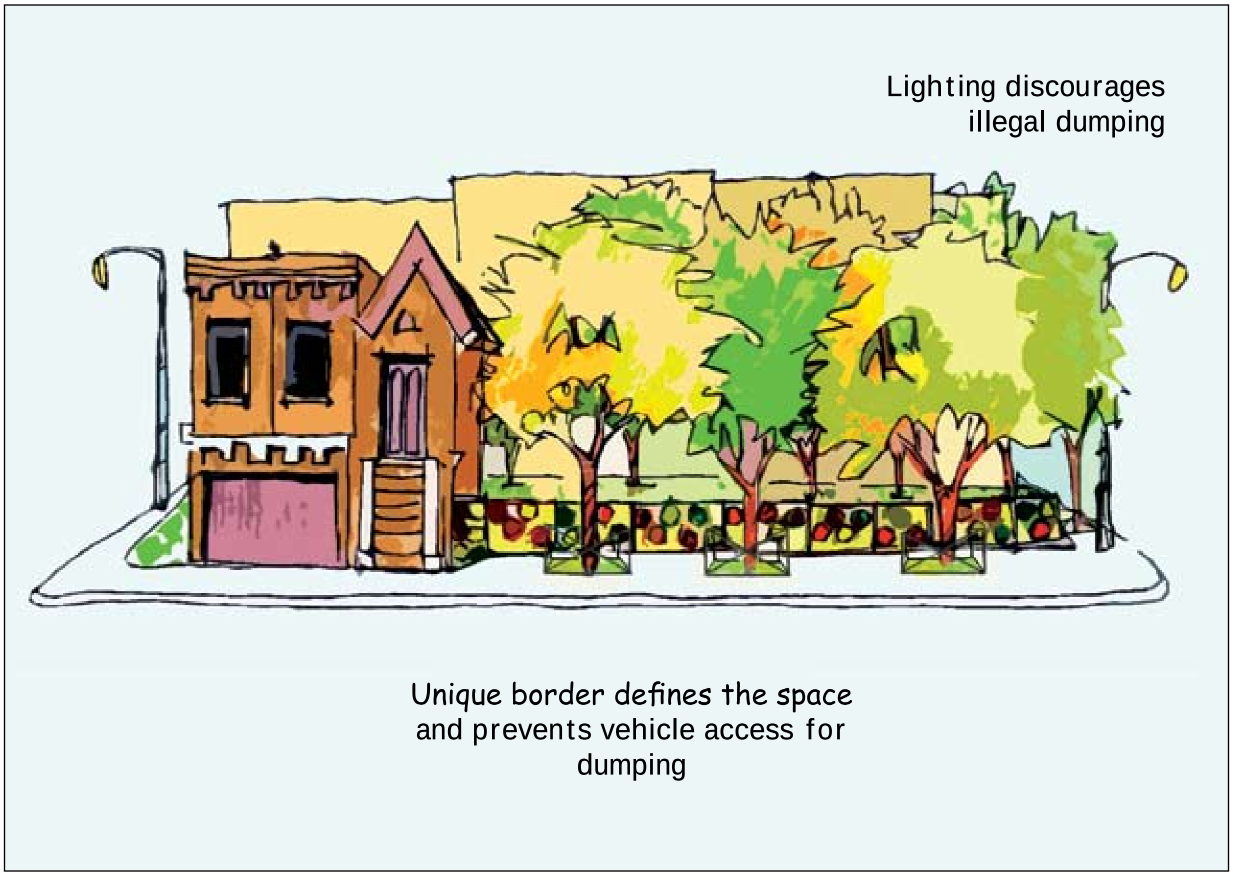


Figure 36. Planting trees in vacant lots--profile

Appendix A. Effect of Land Cover on Runoff and Nutrient Loads in a Watershed

Most urban watersheds are a mosaic of forest, turf, and impervious cover. Traditional monitoring efforts have been unable to distinguish the relative contribution of each type of cover to nutrient loading. With the advent of source area monitoring, however, it is now possible to estimate how much each cover type contributes to nutrient loading in urban watersheds.

As noted earlier, forest cover is the highest and best use of land in a watershed, in terms of reducing excess nutrient runoff. Forests act as a sink for nutrients and lock them up in live and dead biomass, as well as soils. As a result, measured nutrient concentrations in forest runoff are quite low (Table A-1). Turf, on the other hand, generates much higher nutrient levels, according to source area monitoring of both fertilized and unfertilized lawns. Impervious cover produces intermediate nutrient concentrations that reflect the washoff of nutrients deposited from the atmosphere, car exhaust, or household pets.

Table A-1. Median Nutrient Concentrations in Storm Water (milligrams per liter)

Land Cover	Total Phosphorus	Total Nitrogen
Forest[1]	0.25	1.5
Turf[2]	1.90	9.7
Impervious[3]	0.40	1.9

[1]From Mostaghimi and others (1994) and USGS (1999).
[2]Grand mean of Garn (2002), Waschbusch and others (2000), Steuer and others (1997), and Bannerman and others (1993) turf runoff monitoring data.
[3]Grand mean of all reported impervious cover source area monitoring data in Table 19, page 59 of CWP (2003).

Nutrient concentrations are only part of the story. Forests act as a sponge for rainfall and produce very little, if any, storm water runoff. The forest canopy intercepts rainfall, and the remainder soaks into the forest floor. Forest monitoring has shown that less than 5% of rainfall falling on a forest is converted into runoff, which is referred to as the runoff coefficient:

Land Cover	Runoff Coefficient
Forest	[1]0.05
Turf	[2]0.10
Impervious	[3]0.95

[1]Measured runoff coefficient from Mostaghimi and others (1994).
[2]Average for B and C soil types from Legg and others (1996) and Pitt (1987).
[3]Regression of 40 sites nationally in Schueler (1987).

Turf cover, on average, has a runoff coefficient twice as high as forest, although the coefficient tends to vary considerably depending on the soil type, age, and compaction of the lawn (range = 0.05 to 0.30). As might be expected, nearly all the rain that lands on impervious cover is converted into storm water runoff.

The product of runoff volume and concentration yields the annual nutrient load (Table A-2). Clearly, forests are the most desirable form of watershed cover when it comes to nutrient loading. For example, an acre of turf is calculated to produce 15 times more nutrients than an acre of forest cover. The difference is even more significant when forest cover is compared with impervious cover—over 25 times more nitrogen and phosphorus are lost from impervious cover. The nutrient benefits of maintaining forest cover (or increasing it by converting turf to forest) can be impressive at the watershed scale.

Table A-2. Annual Nutrient Loads in Storm Water (pounds per acre per year)[1]		
Land Cover	Total Phosphorus	**Total Nitrogen**
Forest[2]	0.1	0.6
Turf[3]	1.6	7.9
Impervious[4]	2.8	14.7

[1]As computed by Simple method, 40 inches of annual rainfall, using EMCs and Rvs from part 1 and 2, Schueler (1987).

[2]Within range of measured loadings from Gardner and others (1996); Mostaghimi and others (1994); Blackburn and Wood (1990); and McClurkin and others (1985).

[3]No annual nutrient loading data for turf cover available for comparison.

[4]Within range reported by Schueler and Caraco (2002).

Appendix B. Sources of GIS Data for Watershed Forestry

One of the most important questions to ask when beginning mapping for small watershed restoration is "What GIS data is available for my watershed?" Typical data you will use for watershed forestry planning are listed in Table B-1.

Table B-1. Useful Mapping Data for Watershed Planning

Category	Data Layers	
Hydrogeomorphic Features	• Topography • Perennial streams • Surface water features	• Wetlands • 100-yr floodplain • Soils
Boundaries	• Watershed boundaries • Subwatershed boundaries	• Municipal boundaries • Parcel boundaries
Land Use and Land Cover	• Aerial photos • Land use • Zoning • Impervious cover (roads, buildings, parking)	• Forest cover • Turf cover • Stream buffers • Protected land
Utilities	• Sanitary sewer lines • Storm drain network • Storm water treatment practices	• Storm water outfalls • Sewer service areas • Other utilities
Special Areas	• Historic and cultural sites • Rare, threatened or endangered species	• Other critical natural resource or conservation areas
Stream Condition	• Monitoring stations	• Impaired stream segments

Lack of available data can be a huge limitation in using GIS mapping for urban watershed restoration. Some GIS data is available free either online or from local sources, such as county planning offices, which are a great data resource. Two important pieces of data that are typically difficult to find or expensive to purchase are aerial photos and impervious cover layers. If the cost of purchasing high-resolution aerial photography is prohibitive, you may wish to hold off on purchasing any photos until you have chosen priority subwatersheds for further assessment. Then you can purchase just the aerial photos for those subwatersheds. Another option is using inexpensive lower resolution photos (Digital Orthophoto Quadrangles) from the U.S. Geological Survey. Impervious cover layers may not exist for your watershed but can be digitized from aerial photos or estimated based on land use. Online sources of GIS data and other products follow.

National Data

EPA Better Assessment Science Integrating point and nonpoint Sources (BASINS)
www.epa.gov/waterscience/basins/b3webdwn.htm Order CD (free) or download software from Web site. Contains various natural resource data, base map layers, environmental monitoring data (station locations), and point source data (Superfund sites, industrial facilities discharge sites, toxic releases).

EPA STORage and RETreival (STORET)
www.epa.gov/storet/ Repository for national water quality, biological and physical monitoring data. Includes a training exercise to help with downloading data and importing into Excel. Data is downloadable in tabular format and may be input into GIS.

EPA Watershed Assessments, Tracking and Environmental Results (WATERS)
www.epa.gov/waters/data/downloads.html
Download GIS layers of 303(d) listed waters (impaired waters) and 305(b) water quality assessments (monitoring data).

ESRI
www.esri.com/data/download/index.html
Contains a wealth of technical resources for GIS software, downloadable data layers, and downloadable GIS software called ArcExplorer.

Federal Emergency Management Agency (FEMA) Flood Map Store
www.msc.fema.gov/ordrinfo.shtml
Digital Q3 flood data available to order for $50 per county.

GIS Data Depot's GeoCommunity
http://data.geocomm.com
Download 1:24,000 Digital Elevation Models (DEMs), Digital Orthophoto Quadrangles (DOQs) and other data at state or county level for free or very low cost.

MapMart
www.mapmart.com
Download or order USGS products at very low cost, also order high resolution aerial photos and other data at reasonable cost.

National Atlas
www.nationalatlas.gov/atlasftp.html
Download various national data layers in the following categories: agriculture, biology, boundaries, climate, environment, geology, history, map reference, people, transportation, and water. May be useful for more obscure layers such as extent of invasive species habitat.

National Wetlands Inventory (NWI)
http://wetlands.fws.gov/downloads.htm
Download wetlands data. NWI is available digitally for 40% of the conterminous United States.

Natural Resources Conservation Service (NRCS) State of the Land
www.nrcs.usda.gov/technical/land/aboutmaps/coverages.html
Download 8-digit Hydrologic Unit Code (HUC) watershed boundaries and various other boundary layers such as counties, Federal lands, and congressional districts.

NRCS State Soil Geographic Database (STATSGO)
www.ftw.nrcs.usda.gov/stat_data.html
Download soil layers for U.S. states. This layer is most useful for counties with no SSURGO data available.

NRCS Soil Survey Geographic Database (SSURGO)
www.ftw.nrcs.usda.gov/ssur_data.html
Download soils layers for counties. Not available for all counties.

Space Imaging
www.spaceimaging.com
Purchase high-resolution Ikonos satellite imagery. Can be very expensive.

U.S. Bureau of the Census Topologically Integrated Geographic Encoding and Referencing System (TIGER)
www.census.gov/geo/www/tiger/index.html
Download TIGER/Line files from the year 2000 and earlier by state. These files include roads, railroads, rivers, lakes, legal boundaries, and census statistical boundaries. Requires special conversion tools to use in GIS.

USGS Geographic Data Download
http://edc.usgs.gov/geodata
Download the National Hydrography Dataset, 1:24,000 Digital Line Graphs and national scale Land Use/Land Cover, Digital Elevation Models, and Digital Line Graphs. Contains information on obtaining other USGS map products.

USGS Seamless Data Distribution
http://seamless.usgs.gov/website/Seamless/
Download high-resolution orthophotos, National Elevation Dataset, National Land Cover Database, and various other layers using interactive map.

USGS Earth Explorer
http://edcsns17.cr.usgs.gov/EarthExplorer/
Purchase reasonably priced satellite imagery, aerial photos, Digital Line Graphs, elevation data, and Digital Raster Graphics.

Chesapeake Bay Regional and Local Data

Canaan Valley Institute
http://canaanvi.org/gis/gis_links.asp
Contains links to downloadable GIS layers for Maryland, Pennsylvania, West Virginia, and Virginia.

Chesapeake Bay Program FTP Site
ftp://ftp.chesapeakebay.net/pub/Geographic/
Download Arc/Info export files for the Mid-Atlantic, Chesapeake Bay, or individual states, including hydrography, land cover, political boundaries, transportation and watershed boundaries (HUC 8, HUC 11).

Chesapeake Bay Program (CBP) Resource Lands Assessment
www.chesapeakebay.net/rla.htm
Download Bay-wide GIS data results of CBP model scenarios. Data includes ranking of lands by importance to: Prime Farmland, Ecological Network, Water Quality Protection, Forest Economics, Cultural Assessment and Vulnerability to Development.

Maryland Department of Natural Resources Geospatial Data
http://dnrweb.dnr.state.md.us/gis/data/data.asp
Download 4-meter Digital Orthophoto Quadrangle Quarters (DOQQs), floodplains, wetlands, protected lands, and other data layers for Maryland by county.

Pennsylvania Spatial Data Access
www.pasda.psu.edu/
Download various GIS layers for Pennsylvania by county or watershed.

Radford University Department of Geography Geoserver
www.radford.edu/~geoserve/main_page.html
Contains downloadable Digital Raster Graphics and Digital Elevation Models for Virginia, Maryland, Washington, DC, and West Virginia.

Towson University Center for GIS
http://chesapeake.towson.edu/data/download/
Download satellite imagery and other GIS data for the northeastern United States.

West Virginia GIS Data Clearinghouse
http://wvgis.wvu.edu/data/data.php
Download various GIS layers for West Virginia.

Mapping Tools

EPA Surf Your Watershed
www.epa.gov/surf/

Terraserver
www.terraserver.com

TIGER Map Service
http://tiger.census.gov/cgi-bin/mapbrowse-tbl

Appendix C. Methods for Deriving Land Cover Coefficients

This Appendix describes the general methods to derive land cover coefficients for use in the Leafout Analysis. Table C-1 presents impervious cover coefficients for various land uses, for four urban and suburban counties in the Chesapeake Bay Watershed: James City County, VA, Baltimore County, MD, Howard County, MD, and Lancaster County, PA (Cappiella and Brown, 2001). These coefficients can be generalized beyond the individual counties in which they were derived, and they are broadly transferable to other Chesapeake Bay communities with similar development patterns.

Table C-1. Impervious Cover Coefficients		
Land Use Category	Number of Samples	Mean Impervious Cover (%)
Agriculture	8	2
Open Urban Land	11	9
2-Acre Lot Residential	12	11
1-Acre Lot Residential	23	14
½-Acre Lot Residential	20	21
¼-Acre Lot Residential	23	28
⅛-Acre Lot Residential	10	33
Townhome Residential	20	41
Multifamily Residential	18	44
Institutional	30	34
Light Industrial	20	53
Commercial	23	72

Source: Cappiella and Brown (2001)

The methods used to derive these impervious cover coefficients are described below. These methods can be modified for use in deriving land cover coefficients for forest or turf.

Methodology

The primary question investigated in this study was this: What is the impervious cover level of various land uses at the development level and at the zoning area level? A specific sampling protocol was needed to address this and other questions. The following major steps comprised the protocol:

Step 1. Select the targeted land use categories and number of sampling units.
Step 2. Delineate land use polygons.
Step 3. Measure impervious cover.

Step 1. Select the Targeted Land Use Categories and Number of Sampling Units

Table C-2 lists the selected land use categories and number of sampling units chosen, as well as a description of each land use category. These categories were chosen based on typical zoning categories within the Chesapeake Bay Region, as well as the variety of land uses within the study areas. In addition, there was a direct attempt to target and derive impervious cover coefficients for land uses that had little or no previous research associated with it (e.g., open urban land, institutional land).

Table C-2. Selected Land Use Categories and Sampling Target		
Land Use	Description	Sample Units
Agriculture	Cropland and pasture lands	10
Open Urban Land	Developed park land and recreation areas, golf courses, and cemeteries	10
Residential		
2-Acre Lots	Ranges from 1.70 to 2.30 acres	10
1-Acre Lots	Ranges from 0.75 to 1.25 acres	20
½-Acre Lots	Ranges from 0.40 to 0.60 acres	20
¼-Acre Lots	Ranges from 0.20 to 0.30 acres	20
⅛-Acre Lots	Ranges from 0.10 to 0.16 acres, includes duplexes	10
Townhomes	5-10 units/acre, attached single family units that include a lot area	20
Multifamily	10-20 units/acre, residential condominiums and apartments with no lot area associated with the units	10
Light Industrial	Developed areas associated with light manufacturing, distribution, and storage of products	20
Commercial	Areas primarily used for the sale of products and services including strip malls and central business districts, does not include regional malls	20
Institutional		
Churches	Churches and other places of worship	10
Schools	Public and private elementary, middle, and high schools	10
Municipal	Hospitals, government offices and facilities, police and fire stations	10
Total		200

The number of polygons sampled for each land use were chosen based on the frequency and variability of land uses or zoning categories. For example, over 120 sample polygons were needed to characterize the range of housing densities within residential zoning. Given the limited resources available for the study, sample targets were kept to 10 or 20 for each land use. Rigorous statistical analysis was conducted to demonstrate that the sample size would still yield information, particularly across certain land use types. Standard statistics of the results, such as the standard error, were used as measures of the reliability of the results. Based on this study design, between two and five polygons were sampled for each land use within each jurisdiction.

Step 2. Delineate Land Use Polygons

The criteria used when selecting land use polygons in the GIS are listed below.

For single family residential polygons:

- For residential land uses, the parcel boundary information was used to first classify parcels based on acreage (shown in the description in Table C-2). Development patterns that most closely matched the land use category (e.g., ¼-acre lots) were selected for sampling. Because most subdivisions do not have uniform lot sizes, subdivisions were selected if the majority of lots or average lot size met the general criteria for the land use category.
- Because of difficulty in finding subdivisions that met the above criteria for polygon delineation, no minimum area was set for the polygon size for residential areas. Instead, it was decided that each residential polygon must include a minimum of five lots.
- Polygons were drawn by following the lot lines of contiguous parcels and excluding areas of "unbuildable" land located in the interior of the polygon. Stream valleys that did not originate within the subdivision were excluded from the land use polygons, as were other "unbuildable" lands, such as floodplains, wetlands, and conservation areas. The basis behind this rule is that not all development sites include these types of characteristics. When predicting future impervious cover, a planner could estimate the areas based on existing mapping and based on local codes and ordinances that determine "unbuildable" acreage. This acreage could then be removed from the total acreage of the planning area.

For other land use polygons:

- Stormwater ponds and open water were not considered to be impervious cover because they generally occupy a small area and are not always associated with a single land use. While water surfaces do act as impervious surfaces in a hydrologic sense, they generally do not have similar consequences on stream quality, watershed health, or pollutant loading, as do more conventional types of impervious cover, such as roads, parking lots, and rooftops.
- Minimum lot sizes were set for agriculture (50 acres), commercial (1 acre), industrial (5 acres), and multifamily (5 acres) categories.

Once a development area was selected, generally the following criteria were used to delineate the polygons:

- Parcel lines were used as guides for drawing the polygon boundaries.
- "Unbuildable" land, such as floodplains, steep slopes, and conservation areas, were not included in the polygons.
- Subdivision lots that were not built out were not included in the polygons.
- Large forested areas located outside parcel boundaries were not included in the polygons.
- Local and arterial roads were included in the polygons if the parcels bordering each side of the road had the same land use.
- If a local or arterial road bordering a parcel had a different land use bordering the other side of the road, only half the road was included in the polygon.

- Interstate and state highways were not included in the polygons.
- Parcel data, such as a business or owner name, was used to verify the land use.
- Orthophotos were also used to verify the land use.

Step 3. Measure Impervious Cover

The methods used to calculate impervious cover are listed below. More specific details on using ArcView for this process are provided in Cappiella and Brown (2001). The general impervious cover calculation steps are as follows:

1. Set up a project in ArcView that includes each impervious cover theme, digital orthophotos, and parcel data.
2. Create a new theme for each land use and digitize polygons based on criteria.
3. Check the polygons against the orthophotos.
4. Calculate the acreage of each polygon in its corresponding data table.
5. Intersect each land use polygon with each impervious cover theme (e.g., commercial roads, commercial parking lots, commercial buildings).
6. Calculate the area of each impervious cover type for each land use polygon.
7. Export the data tables to Excel and sum impervious cover within each polygon and divide by polygon area to get percent impervious cover.

Assumptions

Although the methods used provide an accurate direct measure of impervious cover, there were some assumptions made due to lack of data. Specifically, residential driveways and sidewalks were estimated using the orthophotos for Lancaster County, Baltimore County, and James City County. Using the orthophotos as a guide, a parking lot layer was created for James City County, and a parking lot layer and roads layer were created for Howard County. Additionally, an impervious cover theme was digitized for each jurisdiction that represented any impervious surface not included in the other layers, such as tennis courts, garages, and other paved areas. The major assumptions made for the analysis are listed and described below.

For single family residential polygons:

Sidewalk Estimation

Orthophotos were used to measure the length of sidewalks in each polygon, which was then multiplied by 4 feet (assumed sidewalk width). The resulting numbers were added to the data table for calculation of total impervious cover.

Driveway Estimation

Orthophotos were used to determine an average driveway size for each polygon, which was then multiplied by the number of homes within the polygon. The resulting numbers were added to the data table for calculation of total impervious cover.

For other land uses:

Parking Lots

James City County, VA, was the only jurisdiction without a parking lot layer. Therefore, a parking lot layer was created for the chosen land use polygons, and this layer was included in the processing and calculation of total impervious cover.

Other Impervious Surfaces

Orthophotos were used to digitize an impervious cover layer that included tennis courts, garages, and other impervious surfaces not included in the buildings, parking lots, roads, driveways, or sidewalks layers. This impervious cover layer was included in the processing and calculation of total impervious cover.

Appendix D. Sources of Data for Forest Cover Coefficients

The Leaf-Out Analysis method described in Chapter 2 requires the input of forest cover coefficients that represent the fraction of land that is forest for a given land use. Data is currently lacking for forest cover coefficients; however, it can be assumed that the amount of forest cover for a given land use will vary with development intensity, age of development, prior land use, and local forest conservation or natural resource protection regulations. In Table 5 in Chapter 2, the forest cover coefficients presented for the Direct Forest Conservation Scenario were loosely based on the Maryland Forest Conservation Act Forest Cover Requirements shown in Table D-1.

Table D-1. Maryland Forest Conservation Act Forest Cover Requirements
(Source: Greenfeld and others, 1991)

Land Use	Recommended % Forest Cover
Agricultural and Resource Areas	20-50
Medium Density Residential	20-25
Institutional	15-20
High Density Residential	15-20
Mixed Use and Public Utility District	15
Commercial and Industrial	15

Other potential sources of data for forest cover coefficients were found for Baltimore, MD, the Philadelphia/New Jersey Metropolitan area, Garland, TX, and Brooklyn, NY. These data came from American Forests CITYgreen analyses and the USDA Forest Service, Northeastern Research Stations's Urban Forest Effects (UFORE) model. These data are presented in Tables D-2, D-3, D-4 and D-5.

Table D-2. Baltimore, MD, Urban Forest Effects (UFORE) Analysis
(Source: Nowak and others, 2002a)

Land Use	% Tree Cover
Forest	59.3
Urban Open	48.8
Commercial and Industrial	11.8
Medium and Low Density Residential	32.4
High Density Residential	22.2
Institutional	12.4
Transportation	10.0
Barren	0.8

Table D-3. Philadelphia/New Jersey Metro Area CITYgreen Analysis (American Forests, 2003)	
Land Use	% Tree Cover
Single Family Residential	20
Commercial	2
Multi Family Residential	25
Industrial	6
Transportation	8

Table D-4. Garland, TX, Metro Area CITYgreen Analysis (American Forests, 2000)	
Land Use	% Forest Cover
Medium Density Residential	26
Low Density Residential	13
High Density Residential	7
Commercial	1
Industrial	4

Table D-5. Brooklyn, NY, Urban Forest Effects (UFORE) Analysis (Nowak and others, 2002b)	
Land Use	% Forest Cover
Open Space	21.4
One and Two Family Residential	17.0
Vacant	2.8
Multi-Family Residential	9.2
Public Facilities	8.7
Commercial/Industrial	1.9

Further research is needed to examine relationships between forest cover for various land uses and factors, such as prior land use, age of development, and local conservation regulations, in order to develop more accurate forest cover coefficients that can be applied in the Leaf-out Analysis.

Appendix E. Blank Worksheet for Leaf-Out Analysis

Leaf-Out Analysis Worksheet For Estimating Future Forest Cover in a Watershed

Section 1. Future Forest Cover

Current Protected or Developed Forest Cover:			acres
All protected or developed forest will remain forested.		+	
Priority Forest Area Protected			acres
See section 2 of this worksheet. Default value is zero.		+	
Area of Forest Conserved During Development			acres
See section 2 of this worksheet.		+	
Area Reforested			acres
Default value is zero.		=	
Total Future Forest Cover			acres

Section 2. Forest Conserved During Development

Zoning Category	Buildable Forest (acres)		Priority Forest Protected (acres)		Buildable Forest Remaining (acres)		Forest* Cover Coefficient		Forest Conserved During Development (acres)
Agriculture		-		=		x		=	
Open urban land		-		=		x		=	
2 acre residential		-		=		x		=	
1 acre residential		-		=		x		=	
½ acre residential		-		=		x		=	
¼ acre residential		-		=		x		=	
⅛ acre residential		-		=		x		=	
Townhomes		-		=		x		=	
Multifamily		-		=		x		=	
Institutional		-		=		x		=	
Light industrial		-		=		x		=	
Commercial		-		=		x		=	
Total									

** Use forest cover coefficients that represent forest conservation requirements in your area*

continued

Section 3. Results Summary

Total Current Forest Cover		acres		
	-			
Total Future Forest Cover		acres		
From Section 1 above.	=			
Future Forest Loss		acres		%

Appendix F. Resources for Setting Urban Canopy Goals

In this manual, numerical goals are recommended for forest cover (or, ideally, canopy cover) in urban watersheds. Chapter 2 provides some general guidelines as to what these numerical goals should be for different types of watersheds. These recommendations are based on the data summarized below and should be tailored to the needs of each community.

The first recommendation made in Chapter 2 was to set a numerical target for forest cover for the entire community. Table E-1 lists various canopy goals for metropolitan areas. The 40% goal set by American Forests (2003) is used by a number of communities. This recommendation comes from extensive analysis of urban tree coverage. American Forests measured tree cover in 440 communities and found that most communities in the southeastern United States have more than 60% canopy cover. The potential for tree cover in urban areas was determined to be 60% to 80% canopy cover. Therefore, the 40% goal should be attainable for most communities. Different goals are recommended for metropolitan areas in the southwest and dry west. Total tree cover for these areas should be 25%, while residential areas should have 18% to 35% and commercial areas should have 9%. These are general guidelines only, and each community should set goals that take into account the specific characteristics of their area (American Forests, no date).

Across the United States, tree canopy cover currently falls below this 40% threshold, averaging 27% in urban areas and 33% in metropolitan areas (Dwyer and Nowak, 2000). The Urban Forest Effects (UFORE) web site provides data on current canopy cover for 21 U.S. cities that may be used as a starting point for developing community forest cover targets: www.fs.fed.us/ne/syracuse/Data/data/htm.

Table F-1. Forest Canopy Goals for Metropolitan Areas

Source	Forest Canopy Goal (% cover)
American Forests (2003)	40*
Nowak and O'Connor (2001)	30
USDA Forest Service (1993)	50

*American Forests recommends 40% canopy cover for metropolitan areas east of the Mississippi and the Pacific Northwest.

To date, we are not aware of any communities that have set a numerical target for forest cover at the watershed scale; however, the two studies summarized in Table F-2 do provide a preliminary basis for the recommendations made in Chapter 2. Further research is needed to make more specific forest cover recommendations for urban watersheds.

Table F-2. Forest Canopy Goals for Watersheds

Source	Forest Canopy Goal (% cover)	Summary
Booth (2000)	65	Watersheds with at least 65% forest cover usually had a healthy aquatic insect community (Puget Sound, WA, region)
Goetz and others (2003)	45	Watershed tree cover greater than 45% was correlated with good and excellent stream health, as measured by biological indicators (Montgomery County, MD)

The most extensive data found on canopy goals included recommendations for canopy cover for individual land uses. This is important because although goals may be defined for a larger area such as a watershed or city, the implementation of these goals will often occur at the site level. Table F-3 summarizes recommended or adopted canopy goals for various zoning categories.

Table F-3. Forest Canopy Goals for Various Zoning Categories

Source	Forest Canopy Goal (% cover)			
	Residential	Commercial/ Industrial/ Institutional	Streets and Rights-of-Way	Natural Areas and Stream Corridors
American Forests (2003)	25-50	15	None	None
Botetourt County, VA (2002)	15	10	None	None
City of Chesapeake, VA (2002)	15-20	10	None	None
City of Georgetown, TX (2002)	None	10-25	None	None
City of Manassas, VA (2002)	15-20	10	None	None
City of Suffolk, VA (2002)	10-20	10	None	None
Fauquier County, VA (2002)	15	10	None	None
Georgia Department of Community Affairs (2002)	20	15	None	None
Goetz and others (2003)	None	None	None	65
Greenfeld et al. (1991)	15-25	15-20	None	20-50
Head et al (2001)	40-60	0-40	None	70
Jefferson County, KY (2002)	10-20	0-15	None	None
Portland, OR, Parks and Recreation (2003)	35-40	15	35	30
Prince William County, VA (2002)	10-20	10	None	None
Smithfield County, VA (1998)	10-20	10	None	None
USDA Forest Service (1993)	None	None	50	None

Meteorological models have also been used in determining realistic goals for canopy cover (Luley and Bond, 2002). Table F-4 summarizes the results of one such model (MM5) in estimating current forest cover, proposed (realistic) forest cover, and the maximum possible forest cover for three urban land uses in the New York City area.

Table F-4. Existing, Proposed and Maximum Tree Cover for Urban Land uses Based on a Meteorological Model (Source: Civerolo and others, 2000)

Land Use	Forest Cover %		
	Existing	Proposed	Maximum
Commercial, Industrial and Transportation	14	24	48
Low-Density Residential	33	43	68
High-Density Residential	25	35	41

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