Center for Watershed Protection

URBAN WATERSHED FORESTRY MANUAL

Part 2: Conserving and Planting Trees at Development Sites

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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 the development site and the watershed scales. Topics covered include site assessment, planting design, site preparation and other pre-planting considerations, and planting and maintenance techniques. An Urban Tree 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.

The views expressed herein are solely those of the authors and are not necessarily endorsed by the USDA Forest Service, U.S. Environmental Protection Agency, or the reviewers and contributors to the manual.

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

The Center for Watershed Protection project team included:
- Karen Cappiella
- Tom Schueler
- Ted Brown
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- Tiffany Wright

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LIST OF ACRONYMS USED

BSD	Better Site Design
CRZ	Critical root zone
DBH	Diameter at breast height
FCA	Forest Conservation Act (Maryland)
FSD	Forest stand delineation
HOA	Homeowners' association
IVM	Integrated Vegetation Management
LOD	Limits of disturbance
ppb	Parts per billion
RTE	Rare, threatened, or endangered
SFP	Stormwater forestry practice
STP	Stormwater treatment practice

CHAPTER 1: INTRODUCTION

Why Conserve and Plant Trees at Development Sites?

The purpose of this manual is to present specific strategies and practices that developers, engineers or landscape architects can use to incorporate trees into the design of development sites. The manual outlines three approaches for doing so.

1. Conserving existing trees during construction
2. Integrating trees into stormwater treatment practices (STPs)
3. Planting trees along local roads and in parking lots

Developers, contractors, and landscape architects can conserve and plant trees at new development and redevelopment or infill projects. On forested sites, it is most important to conserve existing forests, particularly high quality stands or large, mature trees (Figure 1). To conserve existing forests, developers should inventory the site to identify the best forested areas to protect, design the development to prevent loss of these trees, and take measures to ensure the protection of remaining trees during and after construction.


Figure 1. Large tracts of forest (left, photo by Randall Arendt) and mature trees (right, photo by Ed Gilman) conserved during development

Where tree conservation is not an option, development sites provide many opportunities to plant new trees, such as in STPs and other pervious areas of the site. While some STPs are not traditionally considered appropriate for tree planting, incorporating trees and shrubs in certain areas of STPs can enhance their aesthetic appeal and improve their performance. For the purposes of this manual, STPs that incorporate trees into their design are referred to as ***stormwater forestry practices (SFPs)***.

The remaining pervious areas of a site that are good but often overlooked candidates for tree planting include local road rights-of-way, landscaped islands in cul-de-sacs or traffic circles, and parking lots. Private lawn areas may also constitute a significant portion of green space at development sites, and developers should certainly strive to conserve or plant trees in lawns as well. Many development sites may have harsh soil and environmental conditions that need to be overcome through appropriate tree selection and proper site preparation prior to planting.

Conserving or planting trees can address forest conservation, landscaping, or other site design requirements. Forest conservation and tree planting enhances the appeal of a development, increasing land and housing values and can also reduce costs for construction and stormwater management. Additional benefits of trees at development sites are summarized below.

Benefits of Trees at Development Sites

Urban forests provide a wide range of environmental, economic and community benefits (such as air quality improvement, reduction of stormwater runoff, water quality improvement, and wildlife habitat). Part 1 of this manual summarizes urban forest benefits that affect watershed health. This part of the manual reviews the benefits that urban trees provide at the parcel scale, particularly those realized by the developer or homeowner. An important note is that some benefits may not be fully realized until the trees reach maturity. Benefits of trees at development sites are summarized below.

BENEFITS OF TREES AT DEVELOPMENT SITES

Economic
- Decrease heating and cooling costs
- Reduce construction and maintenance costs
- Increase property values
- Positively influence consumer behavior

Environmental
- Reduce urban heat island effect
- Enhance function of STPs

Community
- Improve health and well-being
- Provide shade/block UV radiation
- Buffer wind and noise

Economic benefits of trees at development sites

The values of houses in neighborhoods with abundant trees are usually higher then those of comparable houses in neighborhoods without trees (Morales, 1980; Morales et al., 1983; Anderson and Cordell, 1988) (see Table 1 and Figure 2). Neighborhood natural areas also increase the value of properties located nearby (Kitchen and Hendon, 1967; More et al., 1983; Correll et al., 1978) (see Table 1). Additional cost benefits to the developer and ultimately the homeowner can result from conserving existing trees at a development site. Tree conservation can reduce the amount of clearing and grading, paving, and stormwater management needed at sites, reducing infrastructure costs as well as reducing

Figure 2. Healthy trees can increase property values and aid home sales (Photo by Guy Kramer)

mowing costs in the future. Table 1 summarizes the economic benefits of trees at development sites.

Table 1. Economic Benefits of Trees at Development Sites		
Benefit	**Supporting Information**	**Source**
Decrease heating and cooling costs	• Properly placed trees can reduce heating and cooling costs by 10 to 20% on average within 10-15 years after planting • Trees planted next to buildings can reduce summer air conditioning costs by 40%. Direct shading of an air conditioner can increase efficiency up to 10% • Energy use in a house with trees can be 20 to 25% lower per year than for the same house in an open area	Heat Island Group (1996) Parker (1983) Heisler (1986)
Reduce construction and maintenance costs	• Developers who conserve trees can save up to $5,000 per acre for clearing, grading and installing erosion control practices • Developers who conserve trees can save $2,000 to $50,000 to treat the quality and quantity of stormwater from a single impervious acre • Developers who conserve trees can save $270 to $640 per acre on annual mowing and maintenance costs	Schueler (1995) Schueler (2000) WHEC (1992)
Increase property values	• Property values of homes with trees are an average of 5 to 7% and as much as 20% higher than equivalent properties without trees • Two regional economic surveys document that conserving forests on residential and commercial sites can enhance property values by an average of 6 to 15% and increases the rate at which units are sold or leased.	MD DNR (no date) Morales (1980) and Weyerhaeuser Company (1989)
Positively influence consumer behavior	• Consumer ratings of retail establishments was up to 80% higher for business districts with street trees and other landscaping • Survey results indicated that consumers were more willing to travel further, visit more frequently, stay longer and pay for parking in business districts that have trees • Survey participants priced goods an average of 11% higher in landscaped business districts than in districts with no trees	University of Washington (1998)

Environmental benefits of trees at development sites

Trees reduce air temperatures due to the shading effect provided by their canopy and the release of water vapor through evapotranspiration. Even relatively sparse parking lot canopies can exert a significant cooling effect on parking lot climate and vehicle temperatures (Scott et al., 1998). This temperature reduction reduces the volatilization of smog precursors formed in parking lots and also translates into energy savings when trees are planted in appropriate locations near buildings (e.g., the west side of the building and near air conditioning units). Trees further increase comfort by blocking harmful ultraviolet radiation, reducing wind speed and reducing noise from traffic, lawnmowers and other urban sounds. To be effective at reducing noise, a dense, tall, and wide forested buffer should be 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). Trees also create background noises, such as rustling leaves and wind through the branches, that help to muffle other noises (Harris, 1992).

Planting trees in stormwater treatment practices can increase nutrient uptake, reduce stormwater runoff through rainfall interception and evapotranspiration (ET), enhance soil infiltration, provide bank stabilization, increase aesthetic appeal, provide wildlife habitat, provide shading, discourage geese, and reduce mowing costs (Shaw and Schmidt, 2003). While few studies exist that directly quantify these benefits, research is available on rainfall interception and ET rates as well as pollutant removal for individual trees. This data, presented in the text box below, suggests that incorporating trees into STPs may increase their pollutant removal efficiencies. Median pollutant removal efficiencies for standard STPs are presented in Chapter 3. The environmental benefits of trees at development sites are summarized in Table 2.

HYDROLOGIC AND WATER QUALITY BENEFITS OF TREES

Exhibit A below summarizes data on rainfall interception, evapotranspiration and nutrient uptake for a single tree. Based on this data, the potential reduction of stormwater runoff for each tree planted in an STP is 860 gallons per year, and the potential nitrogen reduction for each tree is 0.05 lbs per year.

Exhibit A: Hydrologic and Water Quality Benefits of Trees

Benefit	Per Tree Annual Quantification of Benefit	Source and Description
Rainfall interception	760 gallons of water per tree per year	Annual rainfall interception by a large deciduous front yard tree * (CUFR, 2001)
Evapotranspiration	100 gallons of water per tree per year	Transpiration rate of poplar trees for one growing season (EPA, 1998)
Nutrient uptake	0.05 lbs N per tree per year	Based on daily rate of nitrogen uptake by poplar trees (Licht, 1990)

*for a 40-year old London Plane tree growing in a semi-arid climate

Trees also show enormous potential to remove other pollutants such as metals, pesticides, and organic compounds. The process of using plants to remove contamination from soil and water is called **phytoremediation.** This process has mainly been applied to soil and groundwater but could easily be applied to stormwater runoff. Trees such as poplars that can absorb large quantities of water through evapotranspiration are typically used for phytoremediation because this type of consumption contains and controls the migration of contaminants (USEPA, 1998). Many other plants have the ability to absorb excess nutrients, filter sediments and break down pollutants commonly found in stormwater runoff. One sugar maple (one foot in diameter) along a roadway removes 60 mg cadmium, 140 mg chromium, 820 mg nickel and 5200 mg lead from the environment in one growing season (Coder, 1996).

Table 2. Environmental Benefits of Trees at Development Sites

Benefit	Supporting Information	Source
Reduce urban heat island effect	• Air temperatures can be 4 to 8 degrees F cooler in well-shaded parking lots than in unshaded parking lots. Similarly, air temperature in neighborhoods with mature canopy were 3 to 6 degrees F lower in daytime than in newer neighborhoods with no trees. • Trees reduce surface asphalt temperatures by up to 36 degrees F, and vehicle cabin temperatures by 47 degrees F	McPherson (1998) and Akbari, et al (1992) CUFR (2001)
Enhance function of STPs	• Trees in stormwater treatment practices influence evapotranspiration and capacity for nutrient uptake, aid infiltration, provide bank stabilization, increase aesthetic appeal, provide wildlife habitat, provide shading, and reduce mowing costs	Shaw and Schmidt (2003)

Community benefits of trees at development sites

Trees at development site also provide benefits to the community that are difficult to quantify but are equally important. These include: increased physical comfort due to reduction of wind and noise and provision of shade, aesthetic and sentimental value, improved physical and psychological well-being, enhanced sense of community and increased opportunities for recreation (Figure 3). Overall, trees increase the livability of a community. Trees create a sense of privacy in urban environments, reduce stress, and have been linked to less crime. Table 3 summarizes some of the research on community benefits of trees in neighborhoods.

Figure 3. Trees and natural areas provide many recreational opportunities (Photo by Guy Kramer)

Table 3. Community Benefits of Trees at Development Sites

Benefit	Supporting Information	Source
Improve health and well-being	• Recuperation rates were faster for patients whose windows offered views of a wooded landscape • Less violence occurs in urban public housing where there are trees	Ulrich (1984) Sullivan and Kuo (1996)
Provide shade/block UV radiation	• Trees with the right shade and density can block up to 95% of incoming radiation • Even leafless trees can intercept up to 50% of the sun's energy	Akbari, et al (1992)
Buffer wind and noise	• Depending on housing density, an added 10% tree cover can reduce wind speeds by 10 to 20%, while an added 30% tree cover can reduce wind speed by 15 to 35%. Even in winter, trees can reduce windspeeds by as much as 50 to 90% of summer values. • A belt of trees 98 feet wide and 49 feet tall has been shown to reduce highway noise by 6 to 10 decibels, a rate of almost 50%	Heisler (1989) Akbari, et al (1992)

Regulatory Considerations for Trees at Development Sites

Conserving existing trees and planting new ones at development sites can have regulatory implications, both in the form of incentives and barriers. Depending on local codes and ordinances regulating site design, several regulations may be met by preserving or planting trees at a development site. Additional voluntary or incentive programs may exist that can provide even more reasons to conserve trees, such as tax breaks or density bonuses. Part 1 of this manual provides additional detail and examples of these regulatory and incentive programs that relate to forest conservation and Table 4 summarizes regulations related to conserving and planting trees at development sites.

Table 4. Regulations Related to Conserving and Planting Trees at Development Sites	
Regulation	**Description**
Landscaping	Landscaping is typically required in parking lots in the form of a minimum percentage of the total area. Landscaped buffers may also be required to screen parking lots and other land uses from adjacent roads and developments. Street trees may be required along local roads. Conserving existing trees within these locations or planting new ones will meet most landscaping requirements.
Stormwater management	Through a stormwater credit program, developers can get credits for conserving tracts of forest and may be allowed to subtract this area from the total site area when computing stormwater runoff volumes to treat. In addition, required landscaped areas can also be used for stormwater treatment, meeting both landscaping and stormwater management requirements.
Forest conservation and protection	Regulations may state that a certain percentage of forest must be preserved at each site or that trees of a certain size must be protected.
Conservation of natural areas	Certain regulations such as stream buffer ordinances and floodplain ordinances may exist that require natural areas such as stream buffers, floodplains, steep slopes or otherwise unbuildable areas be protected and preserved during development.
Open space design for subdivisions	Requires clustering of homes on a development site to conserve a certain percentage of natural area such as forest.
Canopy requirements	Typically apply to parking lots or street trees and require a certain percentage of canopy cover to be met within a specified time frame.
Erosion and sediment control	Temporary tree protection devices installed prior to construction can be combined with erosion and sediment control devices and potentially save money.

These same local codes and ordinances governing site development can also limit tree preservation or tree planting in particular areas of a development site, whether intentional or not. While not restricting tree planting, guidelines provided for design of planting strips, such as medians and islands, do not produce an environment conducive to supporting healthy, mature trees. Table 5 summarizes the potential barriers to conserving and planting trees at development sites. While these barriers can sometimes be addressed, it is important to become familiar with local codes before planting.

A recommended approach to address regulatory barriers to tree conservation is to conduct a local site planning roundtable in the community. As part of the local site planning roundtable process, an audit of codes and ordinances governing site development is conducted to identify potential barriers to implementing environmental-friendly site design techniques, such as forest conservation and tree planting. In addition, roundtables help identify language that discourages the use of environmentally-friendly techniques by requiring extra costs or a longer review process, even though the technique may not specifically be prohibited. The goal of the site planning roundtable is to make recommendations for revising the codes and ordinances to allow and encourage the use of the desired site design practices. Additional guidance on site planning roundtables is provided in CWP (1998).

Table 5. Potential Regulatory Barriers to Tree Conservation, Planting and Growth at Development Sites	
Regulation	**Description**
Street trees	Required width of planting area may not provide adequate soil volume for trees. Buffer strip is typically required to be located between the sidewalk and street, further limiting potential rooting space. Setbacks between trees and infrastructure may not be adequate to prevent damage.
Parking lot landscaping	Required size of parking lot islands may not provide adequate soil volume for trees. Setbacks between trees and infrastructure may not be adequate to prevent damage.
Lot design	Required building setbacks and frontages may limit placement of buildings and pavement on the site and decrease the feasibility of conserving remaining forest areas.
Septic systems	Regulations may require clearing of reserve fields at the time of development.
Landscaping for STPs	Guidance may prohibit trees in some or all practices, or within certain areas of practices such as pond embankments.
Floodplain	Within designated floodways, trees may be prohibited (usually regulated by U.S. Army Corps of Engineers)
Subdivision design	Conventional subdivision design standards may not allow for conservation of natural areas such as forest. Road design standards for subdivision may prohibit use of landscaped island in cul-de-sacs.
Parking ratios	Excessive minimum parking ratios can create large unused parking areas that limit potential for tree conservation.
Utilities, signs and lighting	Regulations may not allow tree planting within utility easements or rights-of-way. In urban environments, adequate space for necessary setbacks between infrastructure and trees may not exist, which can result in limited growing space for trees and potential conflicts between trees and infrastructure.

Unique Properties of the Urban Planting Environment

The average life expectancy of newly planted urban trees has been reported to be 10 to 15 years (Urban, 1998). Urban *street* trees may have an even lower life expectancy of 7 to 10 years (Appleton et. al, 2002). Planted in a better environment, these same trees would have a life expectancy of 60 to 200 years. Why such a significant difference? One reason is the harsh planting environment in urban areas that provides poor conditions for tree growth (Figure 4). Another major reason for lowered life expectancy is the lack of maintenance provided for urban street trees. Many municipalities actually find it easier and cheaper to replace street trees on a regular cycle rather than provide adequate conditions and care needed to allow for long-term tree survival. Replacing urban street trees, however, does not offset the additional loss of trees from land development and mortality due to harsh urban microclimate. A study of tree mortality rates in Baltimore found an annual rate of 6.6%. Even when combined with reforestation efforts, this resulted in a net loss in the number of city trees of 4.2% (Nowak, et al, 2004). This reality reinforces

Figure 4. This urban street tree is dying due to stress from harsh urban conditions (Photo Source: Ed Gilman).

the need to prioritize retention of existing established urban trees rather than relying on replanting.

Some common causes of urban tree mortality are summarized in the box below. While not presented in any particular order, one study of urban tree mortality concluded that drought was the most common factor (Foster, 1978). Causes of tree mortality are often difficult to pinpoint because the decline from many impacts can take years to appear.

COMMON CAUSES OF URBAN TREE MORTALITY

- Limited soil volume
- Poor soil quality
- Air pollution
- Construction activities
- Physical damage from lawnmowers, vandalism or vehicles
- Damage from insects or animals such as deer, beaver, rodents, rabbits or other herbivores
- Soil compaction from heavy foot traffic
- Exposure to pollutants in stormwater runoff
- Soil moisture extremes
- Exposure to wind and high temperatures
- Competition from invasive plant species
- Improper planting and maintenance techniques
- Conflicts with infrastructure
- Disease

Limited soil volume

Urban areas often have limited space available for planting due to presence of infrastructure. Highly compacted soils also effectively prevent tree roots from growing outside the tree pit (Figure 5). The average urban tree pit contains only 40 cubic feet of soil; while a large tree needs at least 400 cubic feet of soil to thrive, and optimally 1000 cubic feet (Urban, 1998).

Figure 5. A typical urban tree pit is about four feet by six feet and does not provide adequate soil volume for most trees

Poor soil quality

Most urban soils are highly compacted, have poor drainage, and are low in organic matter and nutrients (Craul, no date). The pH is often elevated from calcium deposits from building rubble, irrigation water and road salt (Craul, no date). Soil compaction from construction and heavy use limits root growth and starves the tree of oxygen, nutrients and water.

Air pollution
Air pollutants such as ozone damage tree foliage and impair photosynthesis (MD DNR, no date). Ozone levels as low as 40 to 60 parts per billion (ppb) have been shown to be harmful to sensitive plant species (Stormcenter Communications, Inc, 2003).

Construction activities
During construction, trees can be damaged by soil compaction, grade changes, root crushing and pruning, damage to the bark, improper pruning of branches, incorrect storage of construction material and dumping of construction wastes (PSU, 1999, see Figure 6). Even if the tree does not appear to be physically harmed, underground root damage may kill the tree later on, which is why protecting the root zone is so important. Some trees will decline slowly over a number of years after construction damage occurs, while others may die quickly. An indirect impact to trees from construction activities results from changing conditions when exterior or interior trees are removed from a group of trees. Trees growing in groups are adapted to each other and to their light, wind and soil conditions. After removal, the remaining trees are subject to windthrow, sunscald and altered soil conditions.

Figure 6. Improper disposal of construction materials and inadequate protection have impacted trees at this construction site

Physical damage from lawnmowers, vandalism or vehicles
Damage to trees caused by mowers is common, particularly where turf is planted around trees. Vandalism may be common in highly urban areas. Damage to trees from vandalism was found to be highest in areas of high child use such as playgrounds or near pubs and bars (Foster, 1978). This same study found that the most common injury to curbside trees was caused by automobiles. Auto wounds lead to fungus decay, which can kill the tree. Auto damage may occur on 81% of sidewalk trees in a business area, particularly those that are located within a short distance of the curb (Foster, 1978).

Damage from insects or animals such as deer, beaver, rodents, rabbits or other herbivores
Damage to trees from deer overbrowsing is common in urban or suburban areas where populations are uncontrolled (Figure 7). Many trees may be cut down to build dams in urban riparian areas where beaver are present. Rodents and other animals may chew on the bark of trees, effectively girdling the tree. Poor planting conditions and other urban stressors can make

Figure 7. Deer browsing on seedling (USDA Photo)

urban trees more susceptible to disease and to pests such as insects.

Soil compaction from heavy foot traffic
Heavy foot traffic in tree planting areas can compact soils, limiting soil drainage and root growth. Street trees are particularly susceptible to trampling damage if appropriate measures are not taken to restrict foot traffic over tree roots.

Exposure to pollutants in stormwater runoff
Urban stormwater runoff can contain moderate to high levels of pollutants such as salt and other deicers, metals, bacteria, pesticides and nutrients. Many tree species cannot tolerate elevated levels of these constituents.

Soil moisture extremes
Paved surfaces are engineered to quickly shed water, often in directions that either deprive trees of adequate soil moisture or leave their roots submerged in excess water (Appleton, et. al, 2002). An increase in impervious surfaces has also been linked to a decline in baseflow and groundwater (CWP, 2003), which further reduces available water for the tree. Poor soil drainage, clogged drainage systems, lack of proper tree maintenance, and significant variation in properties of rootball soil, backfill soil and site soil can also contribute to soil moisture extremes (Hammerschlag and Sherald, 1985). Damage to trees from flooding and drought is most pronounced during the growing season and includes decline in tree growth, disruption of food production and poor nutrient uptake (Coder 1994, Coder, 1999).

Exposure to wind and high temperatures
Urban trees are often planted by themselves and lack protection from the elements. Increased exposure to wind affects tree stability and increase susceptibility to drought. Air temperatures in urban areas are generally higher than non-urban areas due to the urban heat island effect (Figure 8). Urban trees also have increased exposure to solar radiation when planted alone because they receive sunlight from all sides. Urban trees are exposed to lighting at night, which further increases temperature.

Figure 8. Because this tree is surrounded by pavement, it is exposed to high temperatures

Competition from invasive plant species
Invasive plants are common in disturbed urban areas such as roadsides and riparian areas, and can outcompete desirable trees by using up already limited available water and nutrients.

Improper planting and maintenance techniques
Improper planting and maintenance techniques or lack of maintenance can cause damage to or even kill a tree. For example, improper pruning techniques can make trees more susceptible to disease and pests. Improper use of stakes can also cause tree damage or death.

Conflicts with infrastructure
When trees come in contact with pavement or utilities, they can cause damage such as downed powerlines, sidewalk cracking (Figure 9) and heaving or clogged sewer pipes. Preventative or remedial measures to correct this damage may injure the tree, or cause the offending tree to be removed.

Figure 9. A common infrastructure conflict results in tree roots lifting or cracking pavement due to inadequate setbacks between trees and pavement (Photo by Ed Gilman)

Disease
Poor planting conditions and other urban impacts place urban trees under stress and can make them more susceptible to disease and to pests such as insects.

In addition to the above constraints of urban environments, STPs have a unique set of considerations when planting trees, such as increased exposure to urban pollutants and frequent and extended inundation. These unique conditions are described and addressed further in Chapter 3. Part 3 of this manual provides additional detail on identifying and addressing specific planting environment limitations.

CHAPTER 2: HOW TO CONSERVE AND PLANT TREES AT DEVELOPMENT SITES

This chapter describes in detail the steps that can be taken to conserve existing trees during construction and to plant trees at development sites.

Conserving Existing Trees During Construction

The preferred method for increasing tree cover at a development site is to conserve existing trees during construction, particularly where mature trees are present. Existing trees are conserved during construction through a five-step process:

1. Inventory existing forest
2. Identify trees to protect
3. Design the development with tree conservation in mind
4. Protect trees and soil during construction
5. Protect trees and soil after construction

More guidance on conserving trees at development sites can be found in MN DNR (2000), Greenfeld, et al (1991), PSU (1999), and Johnson (2005).

1. Inventory Existing Forest

A natural resource professional such as a forester or arborist should conduct an inventory of existing trees and forested areas at the development site prior to any site design, clearing or construction. Some communities may require a forest inventory, while it may be optional in others. The extent of the inventory will depend on local regulations, lot size, vegetative cover and the extent of development activity. In some cases, the inventory may survey each individual tree, while in others, it may entail a limited sampling of forest stands. Tree preservation ordinances will often dictate the size and types of trees that must be inventoried.

The inventory begins with a site map that includes property boundaries and the location of existing roads, utilities, easements and covenants. Other information that is helpful in the inventory includes: topography, streams (perennial and intermittent), soils (particularly hydric, prime agricultural or erodible soils), steep slopes, stream buffers, critical habitats, adjacent land uses, cultural and historic sites, 100-year floodplains, and non-tidal wetlands (see text box at right).

MAPPING DATA FOR FOREST INVENTORY

- Property boundaries
- Roads
- Utilities
- Easements and covenants
- Topography
- Streams
- Soils
- Steep slopes
- Stream buffers
- Critical habitats
- Adjacent land uses
- Cultural and historical sites
- 100-year floodplains
- Non-tidal wetlands

The next step in the inventory is to survey existing trees and determine their species, condition, and ecological value. Locations of trees and forest stands are marked on maps, along with sampling points, and tree and forest health data is recorded on appropriate field sheets.

The State of Maryland is unique in that it requires an inventory of existing forest at certain development sites under the Forest Conservation Act (see text box). This inventory, called the Forest Stand Delineation (FSD), is used to characterize and map the existing forests on a development site. The FSD results in a map of existing forest, a site vicinity map, forest stand summary sheets, and a narrative of forest stand conditions. The site inventory process required under the Act provides a useful model for evaluating forest conservation priorities at development sites elsewhere. Additional guidance on other methods to inventory existing forest conditions is presented in Table 6. Figure 10 presents a typical FSD map, while copies of FSD forms and field methods are provided in Appendix A.

MARYLAND'S FOREST CONSERVATION ACT

The Forest Conservation Act of 1991 (FCA) was enacted to protect the forests of Maryland by making the identification and protection of forests and other sensitive areas an integral part of the site planning process. The FCA provides guidelines for the amount of forested land retained or planted after the completion of development projects. These guidelines vary for each development site and are based on land-use categories. Where little or no forest exists, the FCA requires that new forests be established by planting trees.

To meet these requirements, information on the condition of the existing forest and a plan for conserving the most valuable portions of the forest are required. Therefore, a qualified resource professional must conduct a Forest Stand Delineation (FSD) and create a forest conservation plan for all development disturbing greater than 40,000 square feet.

Table 6. Forest and Tree Inventory Guidance

Forest Inventory Method/Guidance	Applicability	Source
Maryland Forest Stand Delineation	Method used to delineate and characterize forests on a development site	Greenfeld, et al (1991)
Trees Approved Technical Manual	Methods for natural resources inventory and forest stand delineation used in Montgomery County, MD	MNCPPC (1992)
Volunteer Training Manual	Method used to inventory and evaluate the health of street trees	USDA Forest Service (1998)
A Guide to Preserving Trees in Development Projects	Provides guidance for conducting a tree inventory at a development site	PSU (1999)
Conducting a Street Tree Inventory	Method used to inventory and evaluate the health of street trees	Cornell University (2004)
Conserving Wooded Areas in Developing Communities	Provides guidance for conducting a natural resources assessment at the landscape, subdivision and lot level	MN DNR (2000)

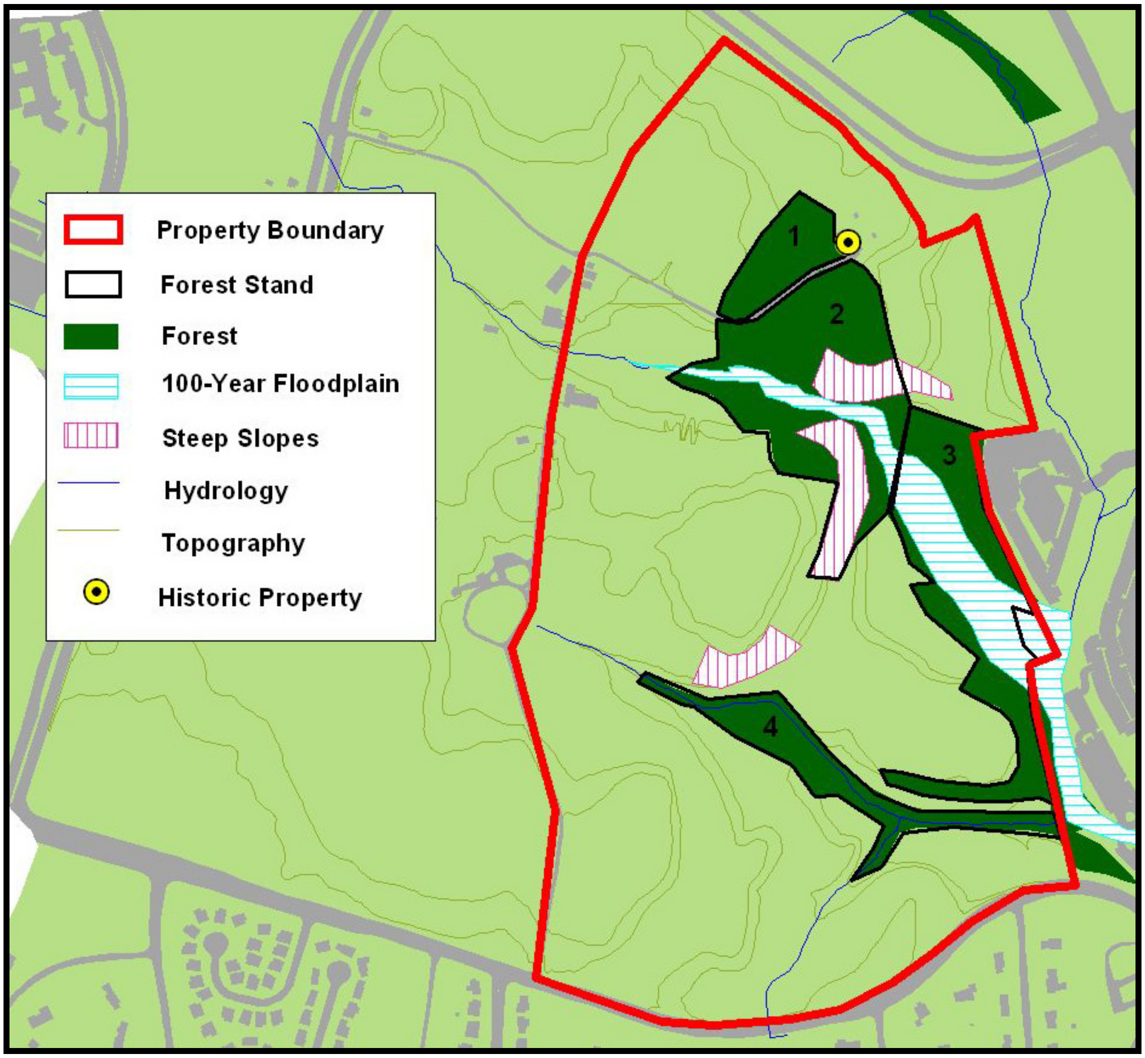

Figure 10. Example map produced for forest stand delineation

The inventory of existing forest has three goals: to comply with local tree preservation or other ordinances, to identify the highest quality trees and forest stands on the site for protection, and to identify and address problems such as invasive species or pest or disease outbreaks. The field assessment portion of the inventory typically collects basic information about the tree species, size and age, as well as the condition of individual trees and suitability for preservation of forest stands.

If the site contains large forest stands, sampling of individual points should be done at a sampling intensity sufficient to characterize the entire stand. Sampling site locations should be selected at random and drawn on map before going to site and flagged in the field. Specific forest stand information collected may include: dominant species and forest association, size class of dominant trees, total number of tree species, number of trees per acre, common understory trees, and a forest structure rating. Appendix A contains forest stand summary sheets and methods for calculating forest structure rating from the Maryland FSD.

The results of the forest inventory should be provided to site engineers and landscape architects prior to site design and layout.

2. Identify Trees to Protect

The forest inventory identifies priority trees or forest stands to conserve and protect during site development. Trees and forest identified for protection should include the minimum needed to comply with local tree preservation regulations and trees located within easements or covenants or other protected areas. Additional selection criteria include tree species, size, condition, and location (see Table 7). Greenfeld, et al (1991) provides additional guidance on prioritizing forest retention areas.

Table 7. Selecting Priority Trees and Forests for Conservation

Selection Criteria for Tree Conservation	Examples of Priority Trees and Forests to Conserve
Species	• Rare, threatened or endangered (RTE) species • Specimen trees • High quality tree species (e.g., white oaks and sycamores because they are structurally strong and live longer than trees such as silver maple and cottonwood) • Desirable landscaping species (e.g., dogwood, redbud, serviceberry) • Species that are tolerant of specific site conditions and soils
Size	• Trees over a specified diameter at breast height (DBH) or other size measurement • Trees designated as national, state or local champions • Contiguous forest stands of a specified minimum area
Condition	• Healthy trees that do not pose any safety hazards • High quality forest stands with high forest structural diversity
Location	• Trees located where they will provide direct benefits at the site (e.g., shading, privacy, windbreak, buffer from adjacent landuse) • Forest stands that are connected to off-site forests that create wildlife habitat/corridors • Trees that are located in protected natural areas such as floodplains, stream buffers, wetlands, erodible soils, critical habitat areas, and steep slopes. • Forest stands that are connected to off-site non-forested natural areas or protected land (e.g., has potential to provide wildlife habitat)

Trees and forests selected for protection should be clearly marked both on construction drawings and at the actual site. Flagging or fencing are typically used to protect trees at the construction site, and tree save areas should be marked on the site map and walked during pre-construction meetings.

If it is infeasible to conserve all of the desired trees at a site, one option to consider is transplanting some of the trees to another location on the site. Transplanting should be done by a licensed arborist or natural resource professional and may be done with equipment that is already available at the site. Guidance on transplanting trees is provided in Bassuk, et al (2003).

3. Design the Development with Tree Conservation in Mind

Once trees and forest are identified for protection, the layout of the site should be designed to conserve these areas, using:

- Open space design techniques to minimize impervious cover and conserve a larger proportion of forest
- Site fingerprinting to minimize clearing and land disturbance
- Setbacks from the critical root zone of trees to be conserved

Developments should be designed to conserve the maximum amount of forest possible by locating buildings and roads away from priority forest conservation areas and by reducing the total areas of graded surfaces. One technique that both reduces grading and conserves forested areas is open space design. Open space design, also known as cluster development, is a compact form of development that concentrates density on one portion of the site by clustering lots in exchange for reduced density elsewhere (Figure 11). Minimum lot sizes, setbacks and frontage distances are relaxed to provide conservation of natural areas such as forests. Open space developments cost less to build because of reduced clearing, paving, stormwater management and infrastructure costs. Open space subdivisions can also bring in higher premiums since people will typically pay more to have a wooded lot or live next to a natural area (see Chapter 1). Open space designs reduce impervious cover by 40 to 60%, thereby conserving significant portions of forest on a site (Schueler, 1995). More guidance on open space design can be found in Schueler (1995), CWP (1998) and Arendt (1996).

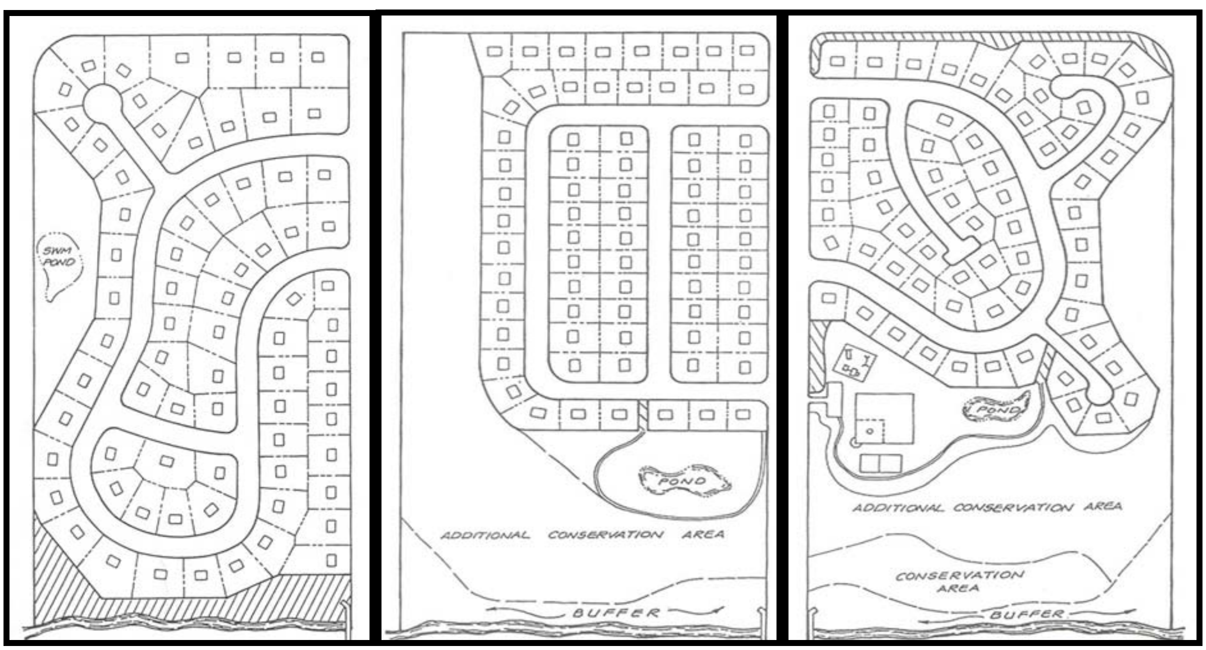

Figure 11. Conventional subdivision (left) with 72 lots, an alternative layout (center) using open space design with the same number of lots, and another alternative layout (right) using open space design with 66 lots (Source: Schueler, 1995).

Site designers should be creative - for example, houses do not always have to be located in the center of the lot and the design can take advantage of trees and forests for window views and focus of outdoor decks and recreational spaces. If open space design is not allowed under existing local site development codes, other techniques can still be applied to reduce impervious cover (CWP, 1998). Some examples of Better Site Design techniques to reduce impervious cover and maximize conservation potential are listed below.

- Design structural elements such as roads and utilities to minimize soil disturbance and take advantage of natural drainage patterns
- Where possible, place several utilities in one trench in order to minimize soil disturbance
- Reduce building footprints by building up, not out
- Use the minimum required street and right-of-way widths
- Use alternative turnarounds instead of cul-de-sacs
- Use efficient street layouts
- Consider shared driveways for residential lots
- Use the minimum required number of parking spaces instead of creating additional spaces

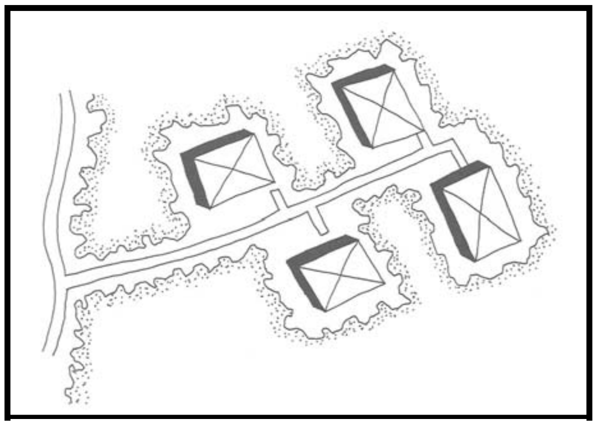
Figure 12. Site Fingerprinting limits site disturbance to the minimum necessary for building (Source: Greenfeld, et al, 1991).

Another method to conserve forests during site design is called site fingerprinting. Site fingerprinting (also known as site footprinting) is a technique that minimizes the amount of clearing and grading conducted at a site by limiting disturbance to the minimum area needed to construct buildings and roadways (Figure 12). A suggested limit of disturbance (LOD) around structures is 5 to 10 feet outward from the building pad (Greenfeld, et al, 1991). No clearing, grading, or siting and construction of utility lines, access roads, staging, storage or temporary parking areas, stormwater management practices or impervious surfaces should be located within the LOD. This requires that designated areas for temporary parking, material storage, construction spoil and holding areas for vegetation and topsoil be established outside the LOD. Designing the site to have only one access point, which coincides with planned roadways, driveways or utilities also limits the amount of clearing necessary. The LOD should be clearly marked both on site plans and at the site.

The LOD should incorporate a field delineation of the critical root zone (CRZ) for trees to be conserved. The CRZ, also called the protected root zone, is a circular region measured outward from a tree trunk representing the essential area of the roots that must be maintained or protected for the tree's survival (Greenfeld, et al, 1991). In order to adequately protect the trees, no disturbance should occur within the CRZ. There are four methods for delineating the critical root zone.

1. *Trunk diameter method* – measure the tree diameter in inches at breast height (54 inches above the ground). For every inch of tree diameter, the CRZ is one foot of radial distance

from the trunk, or 1.5 feet for specimen or more sensitive trees (Greenfeld, et al, 1991, Coder, 1995). Figure 13 illustrates the trunk diameter method.

2. *Site occupancy method* – predict the tree diameter at breast height in inches for that tree at 10 years old. Multiply the number by 2.25 and convert the result into feet to obtain the radius of the CRZ (Coder, 1995).

3. *Minimum area method* – protect an area of approximately 6 feet in radius around the trunk of the tree as the CRZ (MN DNR, 2000).

4. *Dripline method* – measure the distance of the branch that extends horizontally farthest from the trunk and multiply by 1.5 to obtain to CRZ radius. Another option is to project the dripline downward to the ground and delineate the area beneath the tree branches or crown as the CRZ (MN DNR, 2000).

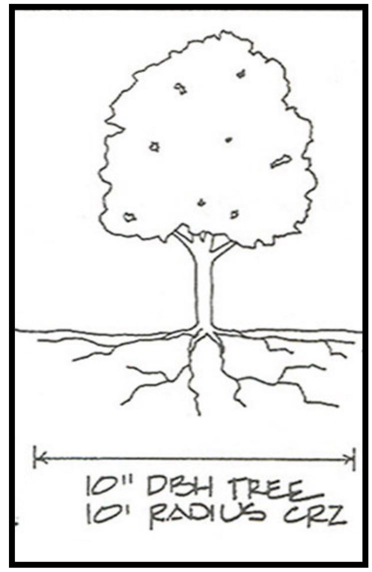

Figure 13. Trunk diameter method for defining the critical root zone (Source: Greenfeld, et al, 1991)

The natural resource professional should select the method of delineation. In general, the dripline method is preferred to protect mature open-growing trees, the trunk diameter method is best for trees growing in a forest or with a narrow growth habitat, and the minimum area method is preferred for very young trees (MN DNR, 2000). These methods do not protect the tree's entire root system but represent a good compromise between tree survival/growth and available space. Other considerations when delineating protected root zone include the following (Greenfeld, et al, 1991):

- *Species sensitivity* - certain species are more tolerant to disturbance or compaction than others. For sensitive species, delineate the CRZ based on species and site evaluation.

- *Tree age* - younger trees are generally more tolerant of disturbance than older ones. For mature trees, delineate a slightly larger CRZ.

4. Protect Trees and Soil During Construction

Physical barriers must be properly installed around the LOD to protect trees to be conserved and their associated CRZ. The barriers should be maintained and enforced throughout the construction process. Tree protection barriers include highly visible, well-anchored temporary protection devices, such as four-foot fencing, blaze orange plastic mesh fencing (see Figure 14), two to three-strand barbed wire fence or snow fencing (Figure 15) (Greenfeld, et al, 1991). Specifications for tree protection methods are provided in Appendix B.

All fencing should have highly visible flags and include posted signs clearly identifying the tree protection area. No equipment, machinery, vehicles, materials, excessive pedestrian traffic, or trenching for utilities should be allowed within protection areas. It may be necessary to install temporary drainage and irrigation for trees and other plants to be preserved.

All protection devices should remain in place throughout construction and penalties for violation should be enforced. A landscape protection contract signed by the builder, developer, contractor and all subcontractors will help ensure compliance.

Figure 14. Orange plastic mesh fencing installed to delineate tree protection areas

Figure 15. Protective fencing around mature tree to be preserved (Source: City of Savannah, GA)

Tree conservation begins by preserving the native soils throughout the site, especially in areas that will be used for planting. Soil stockpiling and mulching can be used to protect the infiltration capacity of these native soils. Soil stockpiling is the temporary storage of topsoil that has been excavated from a construction site. This soil is then reused on the site in planting areas to provide a higher quality growing medium for new vegetation and also saves the builder from having to purchase and haul in new topsoil. Applying a layer of mulch at least six inches thick over areas that will be used for traffic or material storage during construction also helps to prevent soil compaction in areas that will be used for future planting of trees and other vegetation.

5. Protect Trees After Construction

Developers should educate both current and new residents about the existence and benefits of trees in their development. Developers should ensure that a responsible entity is created to maintain forest conservation areas and enforce their boundaries. Some methods to educate residents include: posting of signs and constructing fences to serve as boundary markers; use of covenants that define homeowners' associations (HOA) as being responsible for maintenance of trees, enforcement mechanisms to protect forests from encroachment; and incorporating individual tree maintenance agreements into real estate plats/deeds.

HOAs can distribute pamphlets and other educational materials about the benefits and location of protected forests in their neighborhoods; inform residents of forest protection policies at HOA meetings; organize urban forest walks or inspections to monitor the condition of the urban forest and search for pests and invasive species; and organize planting days to engage residents in tree planting. HOAs can also enforce forest protection policies by inspecting forest conservation areas and mailing correction notices requiring reforestation or other measure, depending on the type of violation. As a last resort, civil fines can be used if notices do not result in cooperation.

Local governments also play an important role in protecting forests after construction by ensuring that appropriate ordinances are enforced to adequately protect forest conservation areas. For example, a community's open space design or forest conservation ordinance should provide specific criteria for the long-term protection and maintenance of natural areas (e.g., should specifically restrict tree clearing except for safety reasons), and should establish appropriate enforcement measures. A third party, such as a local land trust, may be designated responsible to hold and manage forest conservation easements. Land trusts are effective groups to monitor the site and enforce its boundaries, and the third party land trust option should be specifically allowed in the local ordinance. Model ordinances for open space design and tree protection are provided at the links below:

- Open Space Design Model Ordinance: http://www.stormwatercenter.net/Model%20Ordinances/open_space_model_ordinance.htm

- Forest Conservation Ordinance from Frederick County, MD: http://www.stormwatercenter.net/Model%20Ordinances/misc__forest_conservation.htm

Planting Trees at Development Sites

New development sites provide many opportunities to plant new trees, such as in STPs, along local roads and in parking lots. While some STPs are not traditionally considered appropriate for tree planting, planting trees and shrubs in certain areas of specific STPs can enhance their attractiveness and improve their performance. Planting trees at new development sites is done in three steps:

1. Select planting sites
2. Evaluate and improve planting sites
3. Plant trees

1. Select Planting Sites

Potential planting sites in a new development or redevelopment site include portions of local road rights-of-way, such as buffer areas, islands and median strips, parking lot interiors and perimeters, and certain types of stormwater treatment practices (Figure 16). In many communities, some type of landscaping is required in and around parking lots and along residential streets. As such, the developer may have to meet these requirements anyway. Other areas of a development site that may be a priority for planting trees include: stream valleys and floodplains, areas adjacent to existing forest, steep slopes, and portion of the site where trees would provide buffers, screening, noise blockage or shading.

Figure 16. Potential planting areas at development sites

2. Evaluate and Improve Planting Sites

It is important to evaluate and record the conditions at proposed planting sites to ensure they are suitable for planting, select the appropriate species and determine if any special site preparation techniques are needed. A good method for evaluating urban tree planting sites is the site assessment checklist developed by the Cornell Urban Horticulture Institute (Bassuk, et al, 2003). The text box below lists the factors evaluated through this method, while Appendix C contains the full checklist and accompanying guidance for completing it.

SITE ASSESSMENT CHECKLIST FOR URBAN TREE PLANTING

- Site location
- Site description
- Climate
  - USDA hardiness zone
  - Microclimate factors
- Soil factors
  - Range of pH levels
  - Texture
  - Compaction levels
  - Drainage characteristics
- Structural factors
  - Limitations to above-ground space
    - Sunlight levels
    - Irrigation levels
    - Other soil considerations
    - Specific soil problems
  - Limitations to below-ground space (rooting volume)
- Visual assessment of existing plants
- Sketch of site

Site characteristics determine what tree species will flourish there and whether any of the conditions, such as soils, can be improved through the addition of compost or other amendments. Improvements to the planting site generally only apply to smaller spaces; therefore, when reforesting large tracts of land, it is probably not feasible from a cost and labor standpoint to apply soil amendments over the entire planting area. Table 8 presents methods for addressing common constraints to urban tree planting. Part 3 of this manual provides more detail on each specific method.

Table 8. Methods for Addressing Urban Planting Constraints	
Potential Impact	**Potential Resolution**
Limited soil volume	• Use planting arrangements that allow shared rooting space • Provide at least 400 cubic feet of soil per tree
Poor soil quality	• Test soil and perform appropriate restoration • Select species tolerant of soil pH, compaction, drainage, etc • Replace very poor soils if necessary
Air pollution	• Select species tolerant of air pollutants
Damage from lawnmowers	• Use mulch or tree shelters to protect trees
Soil compaction from heavy foot traffic	• Use mulch to protect trees • Plant trees in low-traffic areas
Damage from vandalism	• Use tree cages or benches to protect trees • Select species with inconspicuous bark or thorns • Install lighting nearby to discourage vandalism
Damage from vehicles	• Provide adequate setbacks between vehicles parking stalls and trees
Damage from animals such as deer, rodents, rabbits and other herbivores	• Use tree shelters, protective fencing, or chemical retardants
Exposure to pollutants in stormwater and snowmelt runoff	• Select species that are tolerant of specific pollutants (e.g., salt, metals)
Soil moisture extremes	• Select species that are tolerant of inundation or drought • Install underdrains if necessary • Select appropriate backfill soil and mix thoroughly with site soil • Improve soil drainage with amendments and tillage if needed
Increased temperature	• Select drought tolerant species
Increased wind	• Select drought tolerant species
Abundant populations of invasive species	• Control invasive species prior to planting • Continually monitor for and remove invasives
Conflict with infrastructure	• Provide appropriate setbacks from infrastructure • Select appropriate species for planting near infrastructure
Disease or insect infestation	• Select resistant species

In general, the best way to address urban planting constraints is to ensure each planting project meets the following design principles adapted from Urban (1998) and GFC (2001).

DESIGN PRINCIPLES FOR URBAN TREE PLANTING

1. **Provide adequate soil volume to support tree at maturity.** A general guideline is to provide two cubic feet of usable soil for every one square foot of mature canopy. Design soil volumes of planting areas to be interconnected so trees can share rooting space.

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

3. **Provide adequate space for tree to grow.** Design surrounding infrastructure to accommodate long-term growth of tree. Space trees to allow for long-term growth and management, including removal thinning and replacement of the stand.

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

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

Part 3 of this manual provides guidance on tree species selection in the form of an Urban Tree Database. A useful source for tree selection is the USDA PLANTS database, which can be accessed at http://plants.usda.gov.

3. Plant Trees

Planting trees at new development sites requires prudent species selection, design modifications, a maintenance plan, and careful planning to avoid impacts from nearby infrastructure, runoff, vehicles or other urban elements. Chapter 3 provides specific guidance on planting trees in the following stormwater treatment practices:

- Stormwater wetlands
- Swales
- Bioretention/bioinfiltration facilities
- Filter strips

Chapter 4 provides specific guidance for planting trees in the following pervious areas of a development site:

- Local streets
- Parking lots

Part 3 of this manual provides additional detail on tree planting and site preparation techniques.

CHAPTER 3: STORMWATER FORESTRY PRACTICE FACT SHEETS

This chapter provides detailed guidance for planting trees in stormwater treatment practices (STPs), known as stormwater forestry practices (SFPs). A series of fact sheets are presented with conceptual designs for the following SFPs:

1. Wooded wetland
2. Bioretention/bioinfiltration facility
3. Alternating side slope plantings (swale)
4. Tree check dams (swale)
5. Forested filter strip
6. Multi-zone filter strip
7. Linear stormwater tree pit

The SFP concept designs presented in this chapter are graphical representations only and do not necessarily incorporate all of the items needed for the final design and engineering.

SFPs incorporate trees and shrubs into the design of stormwater wetlands, swales, bioretention or bioinfiltration facilities, and filter strips. Alternatively, conventional tree pit designs can be modified to accept and treat stormwater runoff, thereby functioning as an STP. Traditional landscaping guidance either does not allow or does not address planting trees in stormwater practices (Figures 17-18). Despite the fact that tree planting is rare in STPs, there are many potential benefits to doing so. Research on rainfall interception, evapotranspiration and pollutant uptake of trees indicate that trees in STPs could significantly increase the efficiency of the traditional practice designs (see text box on Page 4). Median pollutant removal efficiencies for standard STPs are presented in Table 9.

Table 9. Median Pollutant Removal (%) of Standard Stormwater Treatment Practices

Stormwater Treatment Practice	Total Suspended Solids	Total Phosphorus	Soluble Phosphorus	Total Nitrogen	Nitrate + Nitrite
Stormwater Wetland	76	49	36	30	67
Bioretention	N/A	65	N/A	49	16
Dry Swale	93	83	70	92	90
Filter Strip (150 foot width)	84	40	N/A	N/A	20

N/A = not available
Sources: Winer (2000), Yu, et al (1993)

Figure 17. Conventional stormwater pond with no trees (left) and two examples with trees incorporated (center photo source: City of Portland, 2004)

Figure 18. Swale in parking lot with no trees (left), and a swale with trees in a median strip (center and right)

The SFP designs presented in this chapter were developed during a series of design workshops attended by stormwater engineers, foresters, arborists and landscape architects. The goal of the workshops was to identify potential limitations to planting trees in STPs, both from an engineering perspective and from the standpoint of tree survival and health. The resulting SFP designs were intended to address these limitations through design modifications, species selection or other methods.

In order to identify which species of trees and shrubs would be best suited to each STP, it was necessary to first identify the conditions within each practice. In addition to the typical urban planting constraints, STPs have other planting constraints that may limit tree growth (Table 10).

Table 10. Characteristics of Stormwater Treatment Practices that May Limit Tree Growth

Characteristic	Stormwater Treatment Practice			
	Stormwater Wetland	Bioretention/ Bioinfiltration	Swale (dry)	Filter Strip
Extremely compacted soils (limited soil volume)	X		X	
Exposure to high winds and high temperatures	X			
Exposure to inundation (frequency, duration and depth varies)	X	X	X	X
Loose, unconsolidated soils, high in organic matter, possibly anaerobic	X	X		
Ice damage/scour	X			
Potential for damage from mowers	X		X	X
Competition from invasive species	X			
High chloride levels		X	X	X
Exposure to high flows during storms (2-6 cfs)			X	X
Exposure to drought during dry periods	X	X	X	
May be used for snow storage		X	X	X
Exposure to moderate to high levels of urban stormwater pollutants (e.g., metals)	X	X	X	X
High sand content of soils (filter media)		X	X	

Perhaps the most common planting constraint in STPs is periodic inundation or saturation of soils by stormwater runoff. Table 11 provides additional detail on the frequency, duration and depth of inundation that trees and shrubs might be exposed to within each of the four groups of STPs. Figure 19 illustrates the four planting zones in stormwater ponds and wetlands.

Table 11. Inundation in Selected Stormwater Treatment Practices

Inundation Characteristics		Stormwater Treatment Practice: Stormwater Wetland Zone I	Stormwater Wetland Zone II	Stormwater Wetland Zone III	Stormwater Wetland Zone IV	Bioretention/ Bioinfiltration	Swale (dry)	Filter Strip
Frequency	Continuous	N/A	X					
	Frequent			X		X	X	X
	Infrequent				X			
Duration	Continuous		X					
	Extended			X	X			
	Brief					X	X	X
Depth	< 6"							X
	6-12"		X			X		
	Depends on planting elevation			X	X		X	

Frequent inundation = 10-50 times per year or more
Infrequent inundation = a few times per year to once every 100 years
Extended duration = 2-3 days or more
Brief inundation = a few to several hours

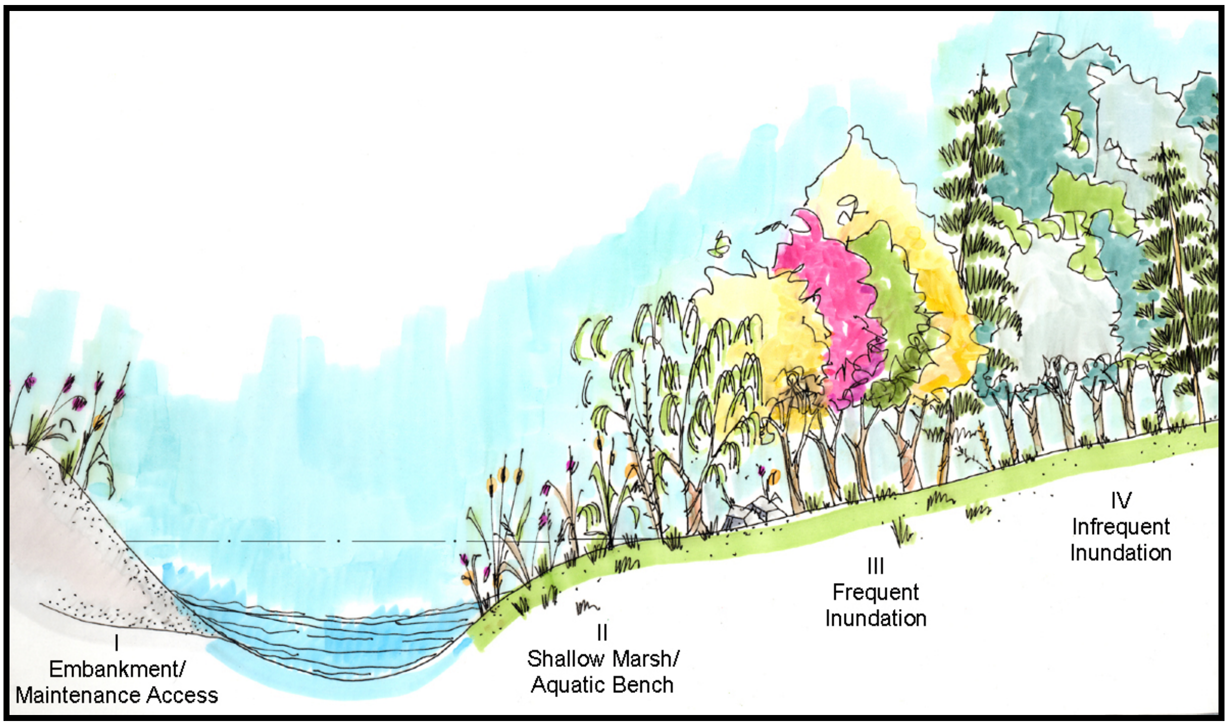

Figure 19. Four planting zones in a stormwater pond or wetland (Graphic by Matt Arnn)

Many of the tree planting constraints within STPs listed in Table 10 can be addressed by selecting species that are tolerant of less than optimal conditions. In addition, species planted in STPs should be able to reduce stormwater runoff (through rainfall interception and evapotranspiration) and mitigate pollutants commonly found in this runoff. Metro (2002) defined a list of characteristics of trees that best perform these functions. Based on this list and on the characteristics presented in Table 10, several desirable characteristics of trees to plant in STPs were defined (see text box on following page). Trees used in STPs should generally have several of these characteristics. Additional detail on which characteristics are appropriate for specific SFPs is provided later in this chapter. Part 3 provides further guidance on species selection.

DESIRABLE CHARACTERISTICS OF TREES FOR STORMWATER TREATMENT PRACTICES

- Persistent foliage
- Wide-spreading, dense canopies
- Long-lived
- Fast growing
- Tolerant of drought
- Tolerant of inundation or saturated soils
- Resistant to urban pollutants (air and water)
- Tolerant of poor soils
- Extensive root systems
- Rough bark
- Tomentose or dull foliage surface
- Vertical branching structure

Table 12 presents the potential engineering conflicts associated with trees in STPs that were identified during the design workshops, and some corresponding design methods to reduce or eliminate these conflicts. These engineering design methods have been incorporated into subsequent SFP concept designs in this chapter.

Table 12. Potential Engineering Conflicts and Resolutions for Planting Trees in STPs

Potential Engineering Conflict	Resolutions
Tree litter may clog outlets and drainage pipes, increasing maintenance, and potentially drowning trees if not unclogged.	• Use alternative outlet structures that do not clog • Select species that do not produce excessive litter
It may be difficult to remove sediment from practices that require periodic sediment removal without harming or removing trees	• Modify practice design so that trees are separate from areas where sediment is deposited (e.g., use a forebay in a wetland)
Trees may shade out grass and contribute to erosion in practices with higher flows	• General consensus was that this should not be a concern. As a precaution, plant shade-tolerant ground covers where possible.
Tree roots may puncture filter fabric or underdrains	• Increasingly, designers are moving away from the use of filter fabric between the filter media and site soil, as it may create an undesirable soil/water interface. To replace the function of the filter fabric where needed, a sand or pea gravel later may be used. • Tree roots clogging or puncturing underdrains should not be a major concern. As a precaution, do not plant trees directly over underdrains.
Presence of trees in practice may reduce storage or conveyance capacity.	• Modify practice design to account for trees (e.g. make it slightly larger).
Mowing around trees may be more difficult where required	• Cluster trees where possible to allow easier mowing • Cease mowing where it is not necessary and allow regeneration. • Use meadow grasses that do not require frequent mowing (if appropriate for the region)
Overgrowth of trees in maintenance areas may limit access	• Limit trees in maintenance access areas and within 15 feet of these areas.
Trees on embankments may compromise stability.	• Do not plant trees within 15 feet of embankment.
Trees with excessive fruits, nuts and other litter may be nuisances, particularly adjacent to impervious surfaces.	• Select species that do not produce excessive litter, particularly when planting near impervious surfaces.

Seven concept designs for SFPs are presented in the remainder of this chapter in fact sheet format. These designs are graphical representations only and do not include all of the items needed for final design and engineering. Each fact sheet contains the following sections:

Description – brief description of practice, where it applies and benefits of incorporating trees.

Design Modifications – modifications to the standard STP to improve planting environment or reduce tree/engineering conflicts.

Species Selection – guidance on desirable species characteristics for planting trees and shrubs in the practice. Part 3 of this manual includes a detailed database of specific tree species and their characteristics.

Planting Guidance – general and specific guidance on how exactly to incorporate trees into the practice.

Maintenance – recommended maintenance for tree-planting areas.

Topics for Future Research – unresolved issues or areas for further research or discussion.

Further Resources - resources for additional information.

This guidance on incorporating trees into STPs is provided as a better alternative to either having no trees at all or allowing uncontrolled growth of volunteer species (Figure 20), which may conflict with the function of the practice and does not necessarily provide ideal habitat conditions.

Figure 20. Overgrowth of willows in this pond limits maintenance access and is essentially a monoculture

Wooded Wetland

Description

A wooded wetland is a variant of a standard stormwater wetland design that provides detention and water quality treatment of stormwater runoff. Most traditional stormwater wetlands contain few, if any, large trees. The wooded wetland design incorporates trees and shrubs into planting zones II, III and IV shown in Figure 19 (page 29).

A wooded wetland is a fairly large practice and typically treats a minimum drainage area of 10 acres or more. This makes it an ideal practice for highway cloverleaves, large residential subdivisions and other large open areas such as parks and schools. The wooded wetland design is shown in Figure 21.

Planting trees in a stormwater wetland can increase water use through evapotranspiration and may increase pollutant removal through nutrient uptake and biological soil processing. Additional benefits include: habitat for wildlife, reduced mowing costs, shading of permanent pool, deterrent of Canada geese and bank stabilization.

Design Modifications

- ☐ Use an alternative control structure such as a weir with a v- or rectangular notch with a hood to prevent clogging by woody debris (see Figure 22). This control structure should be designed to address seepage and uplift on weir wall, for example, by providing for seepage through structure using weepholes or by allowing sufficient travel distance along the base of the weir wall (so it behaves as an anti-seep collar). See USACE (1989) for additional guidance on floodwall and retaining wall design.
- ☐ Include measures to keep pond permanent pools at relatively safe elevations even if outlets have clogged. This alternative, used in Montgomery County, MD, incorporates perforated underdrains surrounded by stone along the face of each dam. The underdrains connect to flow restrictors within the embankment to ensure that the required flow controls are met. The designs also include a small (secondary) riser, which the underdrains and flow restrictors tie into (Figure 23). This secondary riser allows for a small amount of ponding if the underdrains become clogged. The resulting water surface elevation increase is relatively small and still allows for unclogging of underdrain flows without much problem.
- ☐ Use a forebay to trap sediment and allow for sediment removal without removing or injuring trees.

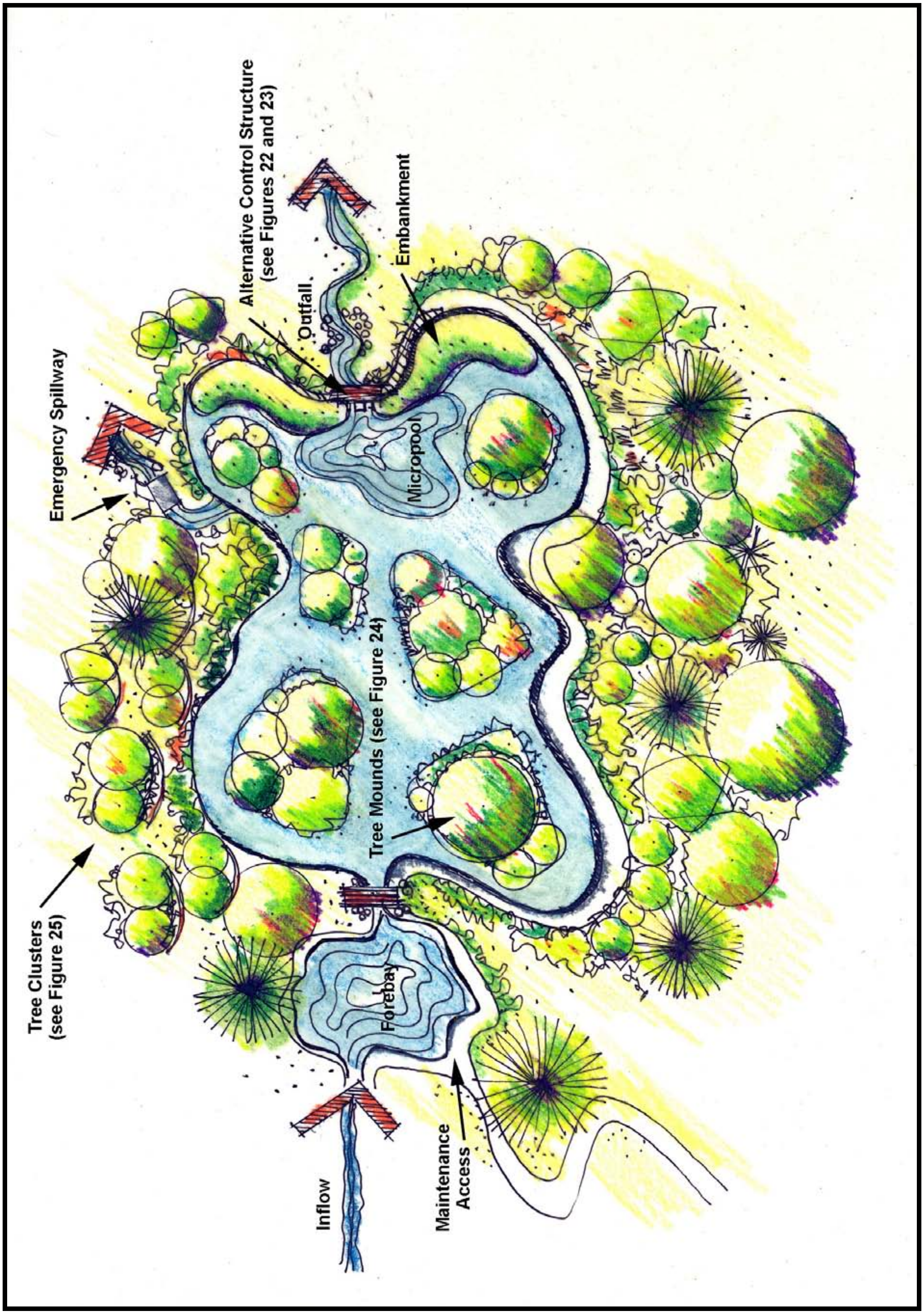

Figure 21. Wooded Wetland (Graphic by Matt Arnn)

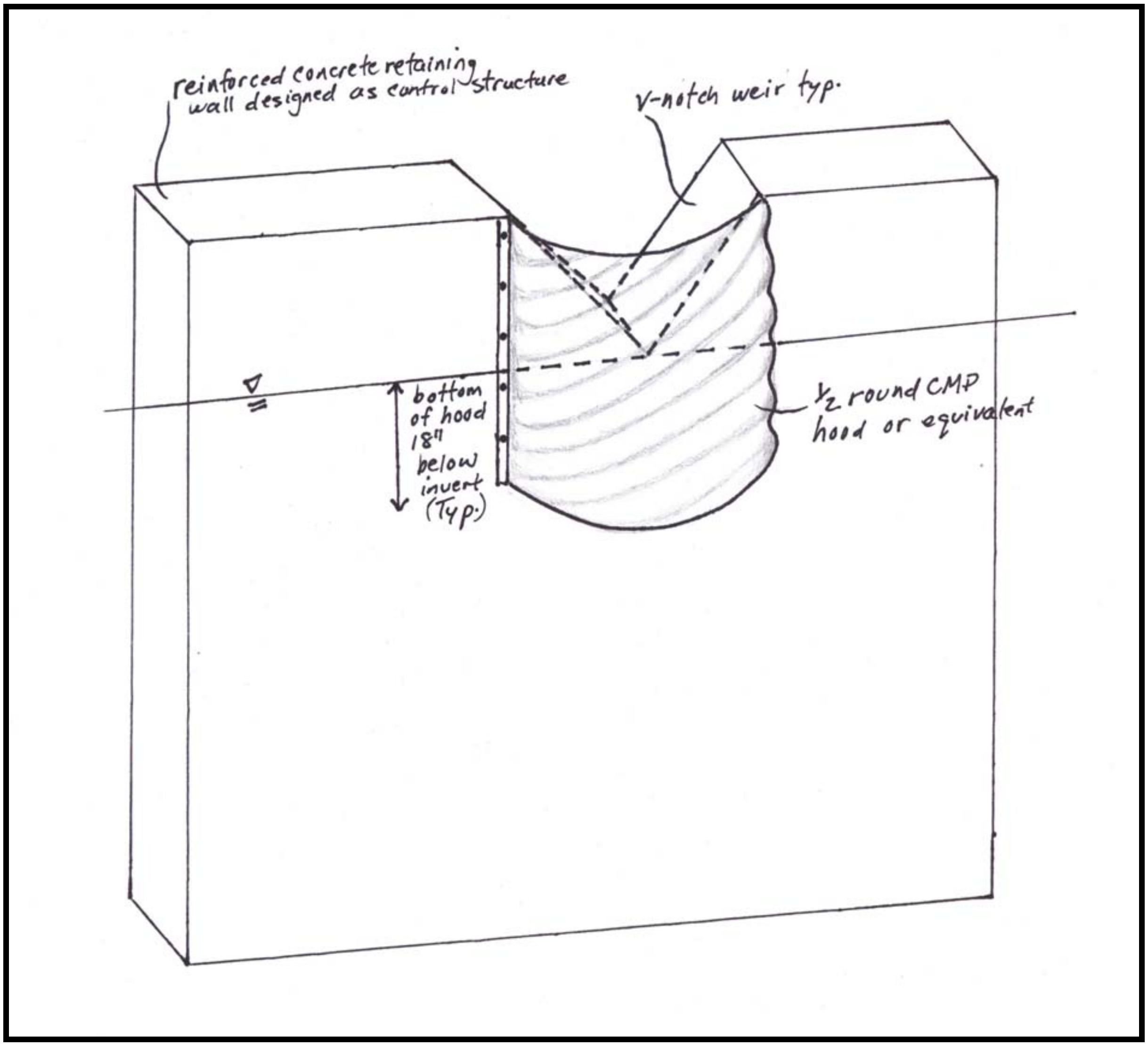

Figure 22. Weir wall

Species Selection

Species selection is key because most site conditions can be addressed by selecting appropriate tree species, rather than trying to modify site conditions. Select a diverse mix of hardy, preferably native species (minimum of three) that are adapted to soils/site conditions. Other desirable species characteristics include the following:

- ☐ Tolerant of compacted soils
- ☐ Tolerant of drought
- ☐ Tolerant of inundation
- ☐ Tolerant of urban pollutants

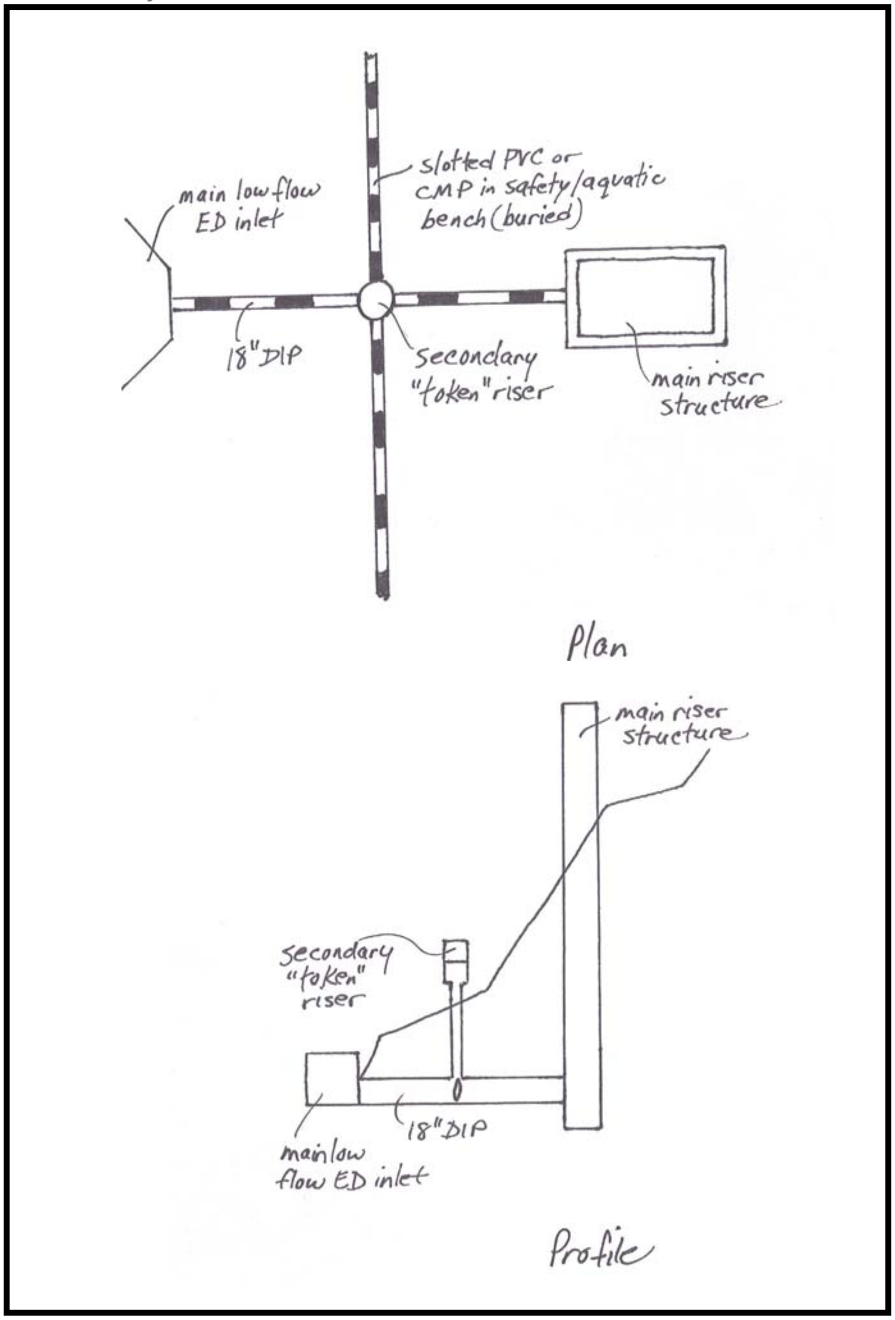

Figure 23. Secondary riser

General Planting Guidance

- ☐ Do not allow trees on embankment or in maintenance access area. Some small shrubs may be allowed (e.g., dogwoods or other 'manageable' vegetation).
- ☐ Do not allow trees within 15' of embankment toe or maintenance access areas. Use permanent pool to enforce this setback.
- ☐ Plant trees on mounds in shallow marsh area (see Figure 24)
- ☐ Plant trees in clusters on side slopes (see Figure 25)

Specific Planting Guidance

Tree Mounds

Tree mounds are islands located in the shallow marsh area of the wetland that are planted with trees. Mound placement should be such that a long internal flow path is created within the shallow marsh area. After initial wetland construction, mark boundaries of mound locations. Excavate area of tree mounds two feet deep, if compacted. Stake coir fiber logs or hay bales, or use rock to form the boundaries of the mound. Backfill holes with amended soil. Mound elevation should be 12-18" above the permanent pool.

Tree mounds should incorporate one large shade tree in and a several small trees or shrubs, depending on the size of the island. Seedlings or whips may be planted, but If larger stock is used, a dedicated water source must be available, and the stock should be from a wetland. Size of islands should directly related to the size and number of trees desired (e.g., provide sufficient soil volume for each tree – usually at least 400 cubic feet).

Tree Clusters

Tree clusters should be used on side slopes ranging from 10:1 to 3:1 to provide additional soil volume and water for trees. Clusters should have a minimum of three trees and contain trees that have the same tolerance for the anticipated degree of future inundation. Tree clusters should be used at various elevations all the way around the slopes and arranged so that any runoff from the sides of the cluster will be directed downhill to the next cluster. Tree clusters should consist of a series of interconnected planting holes to increase available soil volume.

After constructing wetland side slopes, excavate 4-foot deep planting holes for each tree cluster. The size of the hole depends on the ultimate size of the tree but should provide adequate soil volume and holes should be adjacent to each other so trees can share rooting space. Backfill the hole with amended soil. Use spoils to construct a berm on the downslope side of the tree cluster. Elevation of planting hole should be 6" below the top of the berm to allow for some ponding during storm events. Overplant with seedlings or whips for fast establishment and to account for mortality.

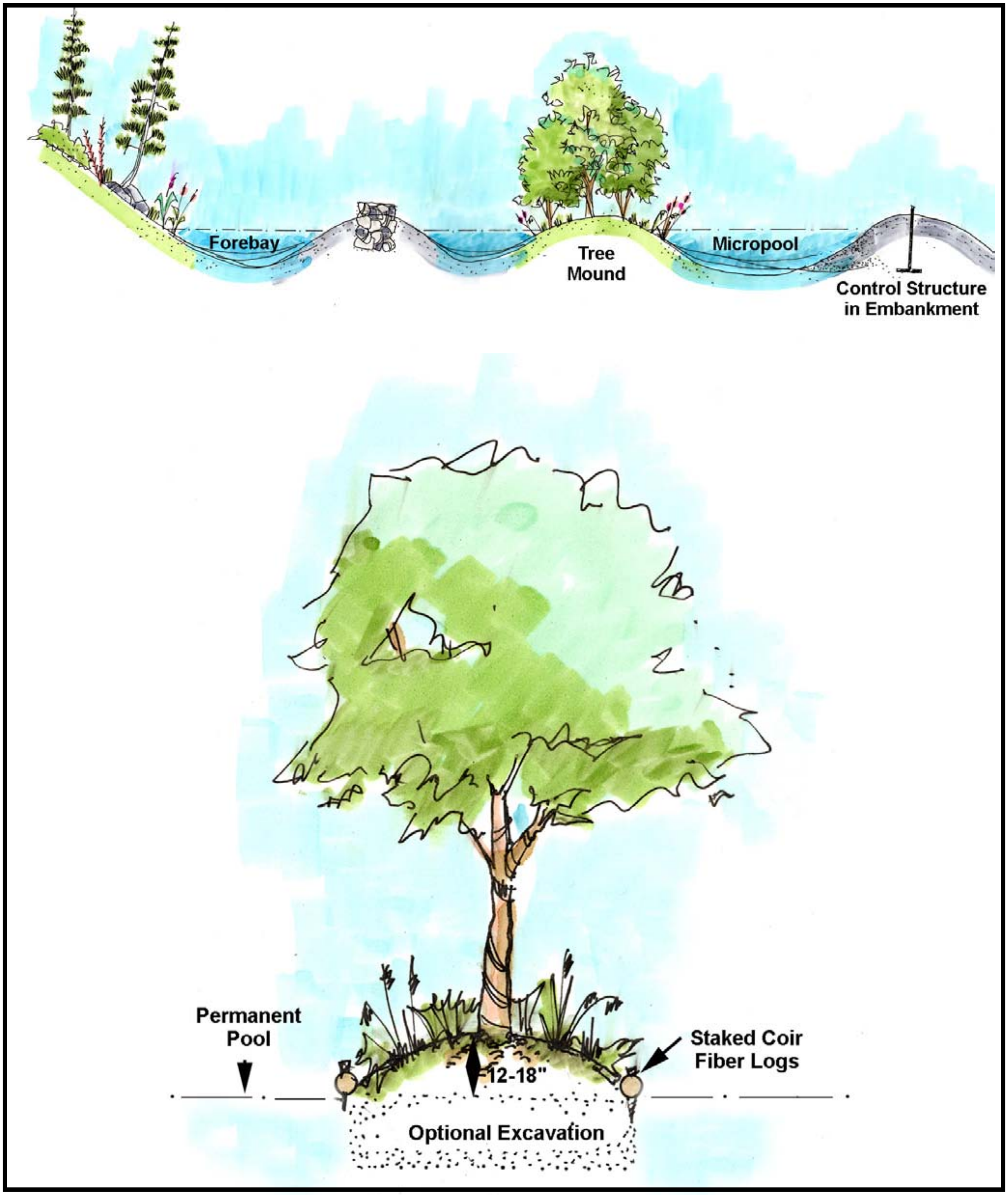

Figure 24. Tree Mound (Graphic by Matt Arnn)

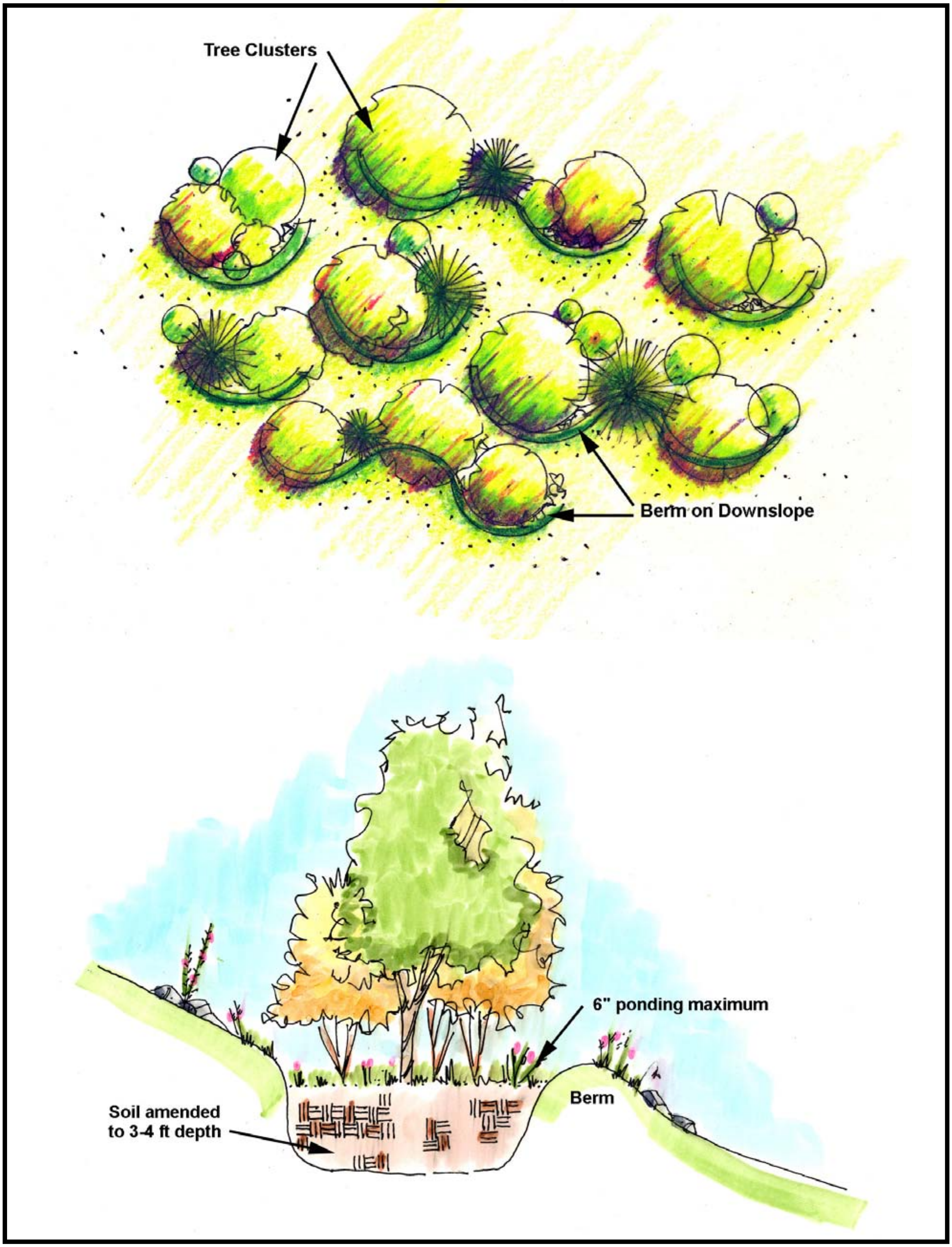

Figure 25. Tree Cluster (Graphic by Matt Arnn)

Maintenance	☐ Plan for minimal maintenance of trees (e.g., frequent watering may not be feasible) ☐ Use tree shelters to protect seedlings from mowers and deer where needed ☐ Use Integrated Vegetation Management (IVM) to control vegetation in embankment and maintenance access areas. IVM entails maintaining low-growing vegetation (e.g., 6 feet) through mowing, hand removal of vegetation, or selection spraying (with herbicide approved for aquatic use) of individual trees in early growing stage (Genua, 2000). ☐ Do not mow wetland side slopes except for initial mowing required when native grasses are used.
Topics for Future Research	☐ Additional guidance is needed on weir wall design or design of alternative outlet structure that resists clogging and addresses seepage and uplift. ☐ Need additional guidance on designing ponds and wetlands to preserve existing trees. ☐ May need alternative to coir fiber logs for mounds near permanent pool. ☐ Measure changes in water quality due to trees in wetlands
Further Resources	Genua, S. M. 2000. *Converting Power Easements into Butterfly Habitats*. Potomac Electric Power Company (PEPCO), Washington, DC. Available online: www.butterflybreeders.org/pages/powerease_sg.html Schueler, T. 1992. *Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetlands in the Mid-Atlantic Region*. Metropolitan Washington Council of Governments, Washington, D.C. U.S. Army Corps of Engineers (USACE). 1989. *Retaining and Flood Walls*. Engineer Manual 1110-2-2502. U.S. Army Corps of Engineers, Washington, DC.

Bioretention and Bioinfiltration

Description

Bioretention and bioinfiltration facilities are shallow, landscaped depressions that contain a layer of prepared soil, a mulch layer, and vegetation, and provide filtering of stormwater runoff by temporarily ponding water during storms. Bioretention facilities have underdrain systems, while bioinfiltration facilities allow runoff to infiltrate into existing site soils (infiltration rates > 0.5 inches per hour).

The standard bioretention and bioinfiltration designs sometimes incorporate trees, but mainly as a landscaping 'afterthought.' The concept design presented here not only incorporates trees and shrubs, but has also been modified to improve growing conditions and decrease potential engineering conflicts (Figure 26). Planting trees and shrubs in bioretention and bioinfiltration facilities may increase nutrient uptake and evapotranspiration.

Bioretention and bioinfiltration facilities are typically small (footprints are generally 5% of the impervious area they receive drainage from, drainage areas are less than two acres) and can be used in many applications. Where space is available, a forested or multi-zone filter strip may be used as pretreatment for bioretention/bioinfiltration facilities.

Design Modifications

- ☐ Filter fabric should not be used between the filter media and the gravel jacket around the underdrain, as it creates an undesirable soil/water interface. A filter layer of sand or pea gravel may be used in lieu of filter fabric in this area to prevent the migration of fines into the gravel layer below. Ferguson (1994) provides a formula for determining the composition of this sand layer and PG County DER (2001) provides guidance on use of a pea gravel layer. Filter fabric may not be necessary along the sides of the excavated area unless there is concern about lateral movement of water into the adjacent soil (e.g., in applications where lateral seepage may cause upheaval of adjacent pavement).
- ☐ Use #57 (e.g., 1 ½" diameter) gravel instead of #2 around underdrain to provide some filtering. The underdrain may be suspended within #57 gravel to provide enhanced recharge/infiltration by increasing the stone reservoir.
- ☐ Allow for 6-9 inches of ponding during storm events

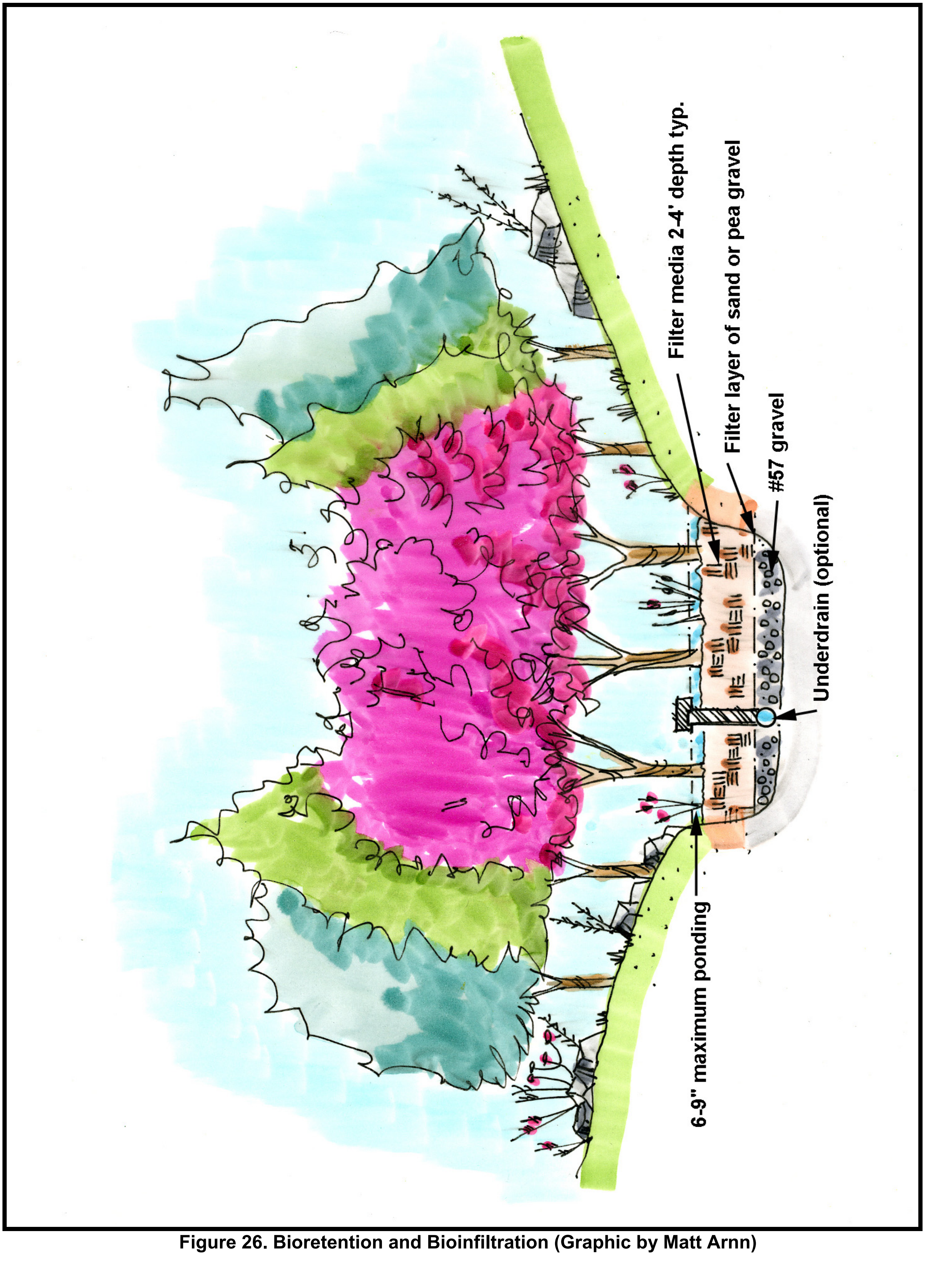

Figure 26. Bioretention and Bioinfiltration (Graphic by Matt Arnn)

Species Selection

Species selection is key in bioretention designs since it is more efficient than trying to change the site characteristics. Select a minimum of three hardy, native tree species that are adapted to soil and site conditions. Other desirable species characteristics may include the following:

- ☐ Tolerant of inundation
- ☐ Tolerant of drought
- ☐ Wide spreading canopy
- ☐ Tolerant of salt

General Planting Guidance

- ☐ Have a landscape architect create a planting plan for the facility.
- ☐ Do not plant trees directly over the underdrain as a precautionary measure.
- ☐ Excavate the center only to a depth of 4 feet and backfill with filter media (infiltration rate of at least 0.5 feet per day). Use existing soil on side slopes (minimum 4:1 slopes). Use a filter media with a lower sand ratio, or plant large trees on side slopes only due to potential for upheaval.
- ☐ Overplant with bare root seedlings or whips for fast establishment and to account for mortality. Alternatively, plant larger stock when a dedicated water source is available using desired spacing intervals (35-50 feet for large and very large trees) and random spacing, or use a mix of whips and larger stock.
- ☐ Provide adequate soil volume for trees: in general, two cubic feet of useable soil for every one square foot of mature canopy (Urban, 1998). Assume some shared rooting space between trees.

Maintenance

- ☐ Use tree shelters to protect seedlings where deer predation is a concern
- ☐ Use mulch to retain moisture.

Topics for Future Research

- ☐ Quantify increased pollutant removal due to trees in facility.

Further Resources

Center for Watershed Protection. 1996. *Design of Stormwater Filtering Systems.* Center for Watershed Protection, Ellicott City, MD.

Ferguson, B. K. 1994. *Stormwater Infiltration*. CRC Press, Inc, Boca Raton, FL.

Prince George's County Department of Environmental Resources Program and Planning Division (PG County DER). 2001. *Bioretention Manual*. Prince George's County, Upper Marlboro, MD.

Urban, J. 1998. Room to Grow. *Treelink* 11:1-4.

Alternating Side Slope Plantings

Description	Alternating side slope plantings are trees planted on the side slopes of a dry swale or other open channel conveyance systems in an alternating pattern. Alternating side slope plantings can be used in open channels with longitudinal slopes up to 2% to provide shade, rainfall interception, limited slope stabilization and aesthetic value.
Design Modifications	None.
Species Selection	Species selection is key because it is more efficient than trying to change the site characteristics. Select a diverse mix of hardy, native species that are adapted to the following planting conditions: ☐ Tolerant of inundation ☐ Tolerant of salt ☐ Wide spreading canopy
General Planting Guidance	☐ Trees should be planted singly or in clusters in an alternating pattern on the side slopes. As a general rule, tree or cluster spacing should be 6 times the channel width (see Figure 27) to impose meanders on channel flow. ☐ Stock can be seedlings or whips (overplant for fast establishment and to account for mortality) or larger stock planted at desired spacing intervals. ☐ Excavate planting hole to a depth of 2-4 feet and backfill with amended soil if existing soil is compacted. ☐ The channel bottom and side slopes may be planted with turf or with native grasses (if able to withstand design velocity). ☐ Establish a defined edge on the top slope of the channel using trees, shrubs or spaced rock. This edge protects trees from mowers and provides a visual border to let residents know the plantings are intentional.

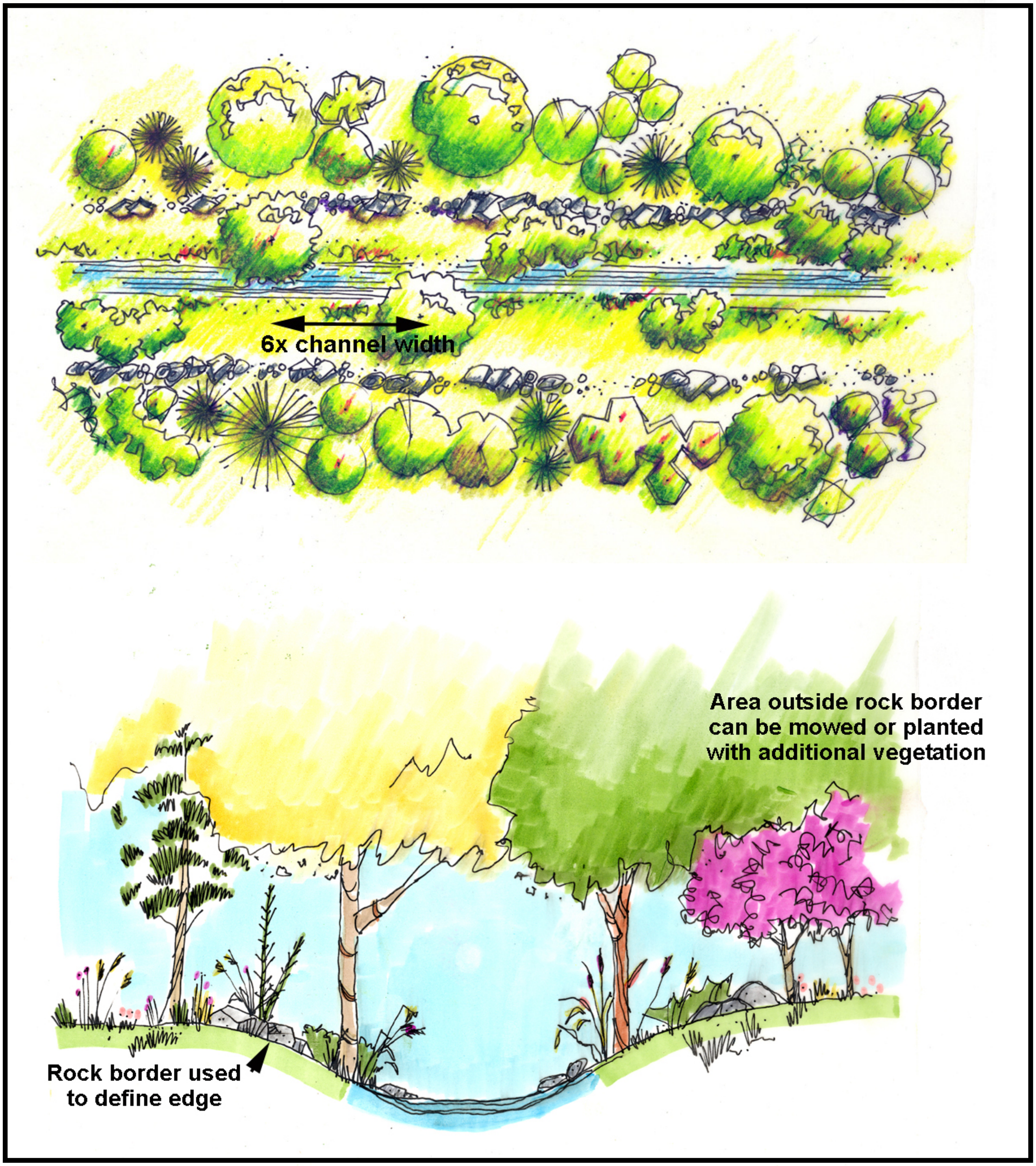

Figure 27. Alternating Side Slope Plantings (Graphic by Matt Arnn)

Maintenance

- ☐ Use mulch to retain moisture
- ☐ Mow around trees regularly if turf, or twice a year if native grasses.
- ☐ Use mulch, tree shelters, or rock borders to protect trees from lawn mowers.

Topics for Future Research

- ☐ Is there potential for trees to shadeout grass and contribute to erosion?
- ☐ What species can be planted on channel bottom and around trees as an alternative to turf that can also withstand design velocities?

Further Resources

Center for Watershed Protection. 1996. *Design of Stormwater Filtering Systems.* Center for Watershed Protection, Ellicott City, MD.

Tree Check Dams

Description

Open channel conveyance systems such as dry swales often incorporate check dams to slow runoff and prevent erosion when longitudinal slopes range from 2 to 6%. Traditional check dams are constructed of rock, railroad ties or other material. Tree check dams use tree mounds to dissipate velocity (Figure 28). Tree check dams may also increase evapotranspiration and pollutant removal in the swale soils.

Design Modifications

- ☐ Account for increased roughness and reduced capacity by subtracting out the cross-sectional area of trees from channel cross-section when computing channel capacity.

Species Selection

Species selection is key because it is more efficient than trying to change the site characteristics. Select a diverse mix of hardy, native species that are adapted to soils/site conditions. In particular, consider the size of trees at maturity in relation to channel width. Trees that are too large may block flow across the channel, so small trees and shrubs may be best for check dams. Other desirable species may include trees that are:

- ☐ Tolerant of inundation
- ☐ Tolerant of salt

General Planting Guidance

- ☐ Spacing of check dams should be such that the toe of the upstream dam is at the same elevation as the top of the downstream dam.
- ☐ Check dam mounds should be no higher than 6-9 inches above the bottom (invert) of the channel.
- ☐ The mound should be constructed across the entire width of the channel, and have a weephole or armored opening to allow ponded water to seep through the mound. Mounds should be armored with rock on downslope side, particularly on steeper slopes to protect from erosion.
- ☐ Excavate to a depth of 4 feet and backfill with amended soil if existing soil is compacted.
- ☐ Plant trees and shrubs on the mounds, using bare root seedlings or whips to minimize transplant stress to roots.
- ☐ Plant turf grass or native grasses (if able to withstand design velocity) along the channel bottom and side slopes.

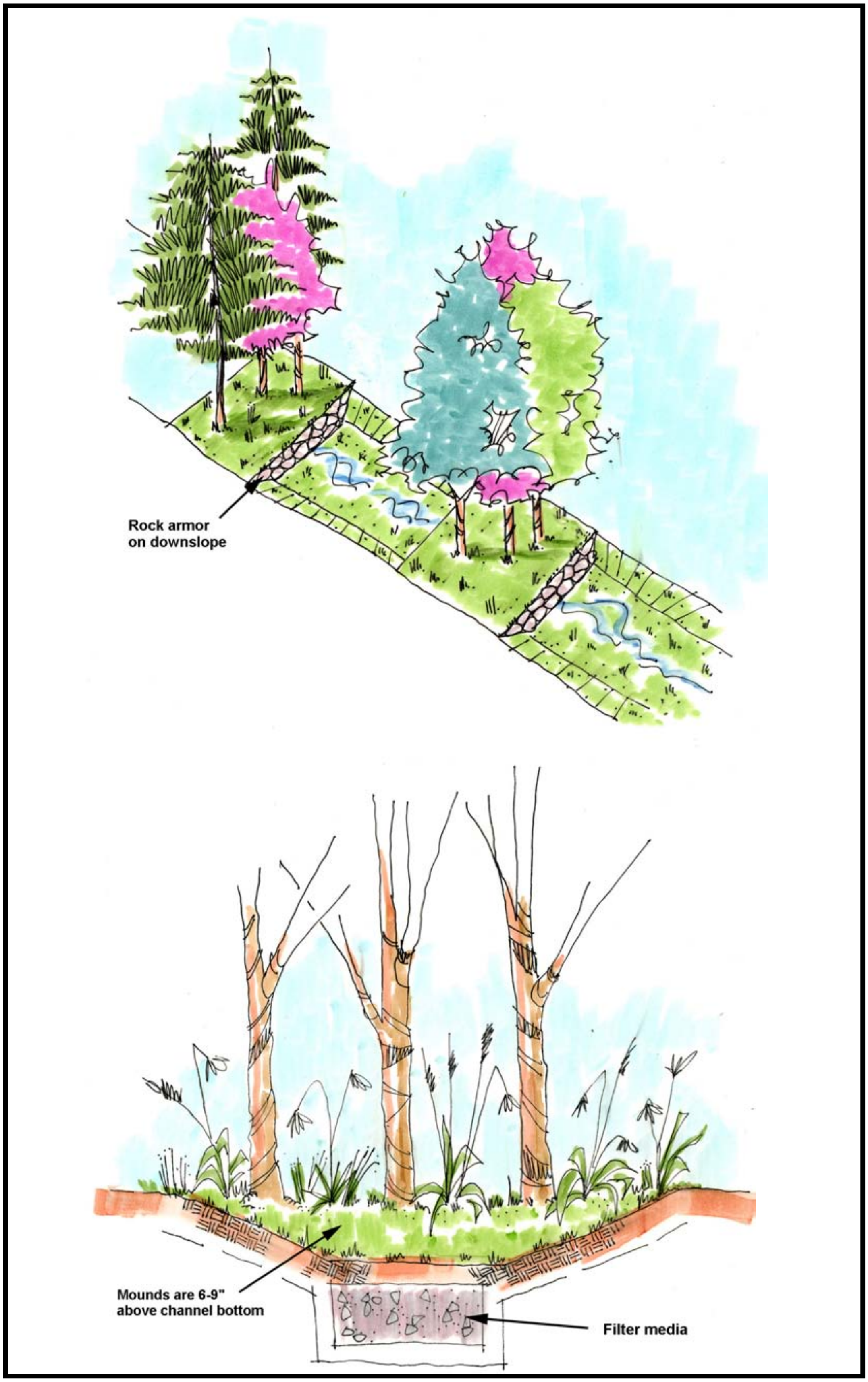

Figure 28. Tree Check Dams (Graphic by Matt Arnn)

Maintenance

- ☐ Use mulch to retain moisture.
- ☐ Periodically remove debris and trash from the check dams
- ☐ Use mulch, tree shelters or rock to protect the tree from lawnmower damage.
- ☐ Mow turf regularly or native grasses twice a year.

Topics for Future Research

- ☐ Will tree mounds be stable enough to withstand high flows?
- ☐ Should larger stock be used to prevent seedlings from washing away?
- ☐ Is there potential for trees to shadeout grass and contribute to erosion?
- ☐ What species can be planted on channel bottom and around trees as an alternative to turf that can also withstand design velocities?
- ☐ Further define dimensions of tree mounds.

Further Resources

Center for Watershed Protection. 1996. *Design of Stormwater Filtering Systems.* Center for Watershed Protection, Ellicott City, MD.

Metro. 2002. *Green Streets. Innovative Solutions for Stormwater and Stream Crossings*. Metro, Portland, OR.

Forested Filter Strip

Description

A traditional filter strip is a grass area that is intended to treat sheet flow from adjacent impervious areas. Filter strips function by slowing runoff velocities and filtering out sediment and other pollutants, and providing some infiltration into underlying soils.

A forested filter strip provides a similar function but incorporates trees and a small ponding zone into the design (Figures 29 and 30). The ponding zone is a small depression with a low berm where water ponds during most storm events (e.g., the water quality storm, typically around a 1" rainfall). The entire filter strip is planted with trees and shrubs, but since the ponding zone is wetter than the remainder of the practice, the two zones are distinguished by referring to them as the *ponding zone* and the *forested zone*. Additional benefits provided by a forested filter strip include: evapotranspiration, wildlife habitat, and infiltration promoted by macropore formation.

Forested filter strips may be used:

- ☐ In linear areas such as stream buffers and transportation corridors.
- ☐ As pretreatment for a stream buffer or other stormwater treatment practice.
- ☐ Where visual screening or a buffer is desired.

Design Modifications

- ☐ Unlike a traditional grassed filter strip, the forested filter strip is not limited to accepting sheet flow runoff. If runoff is concentrated, the flow to the filter strip should be armored with rock.
- ☐ Use a gravel diaphragm for pretreatment (acts as a level spreader and allows fine sediment to settle out where sheetflow is present).
- ☐ A forested filter strip should have a small berm constructed of pervious material such as gravel, rock or earth. If the berm is earthen, insert weephole pipes so ponded water filters to the other side. If the berm is gravel, gabions may be used. The height of the berm should be 6-18 inches above the bottom of the depression and at least 6" below the lowest inflow elevation.
- ☐ Overall dimensions should provide surface storage for the water quality volume. During larger storms, runoff will overtop the berm. Minimum width of the filter strip should be 25 feet. The slope should range from 2 to 6%.

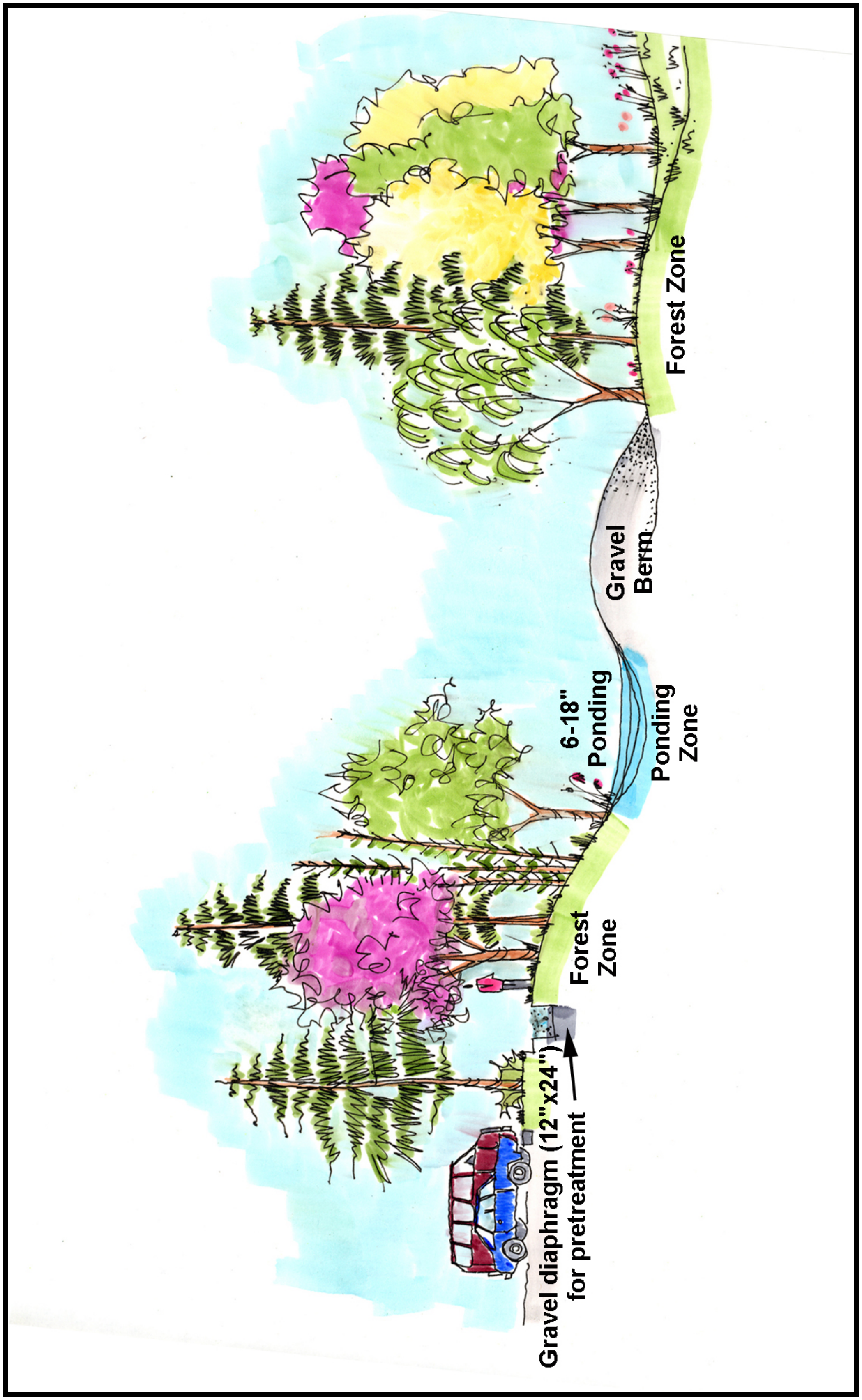

Figure 29. Forested Filter Strip profile (Graphic by Matt Arnn)

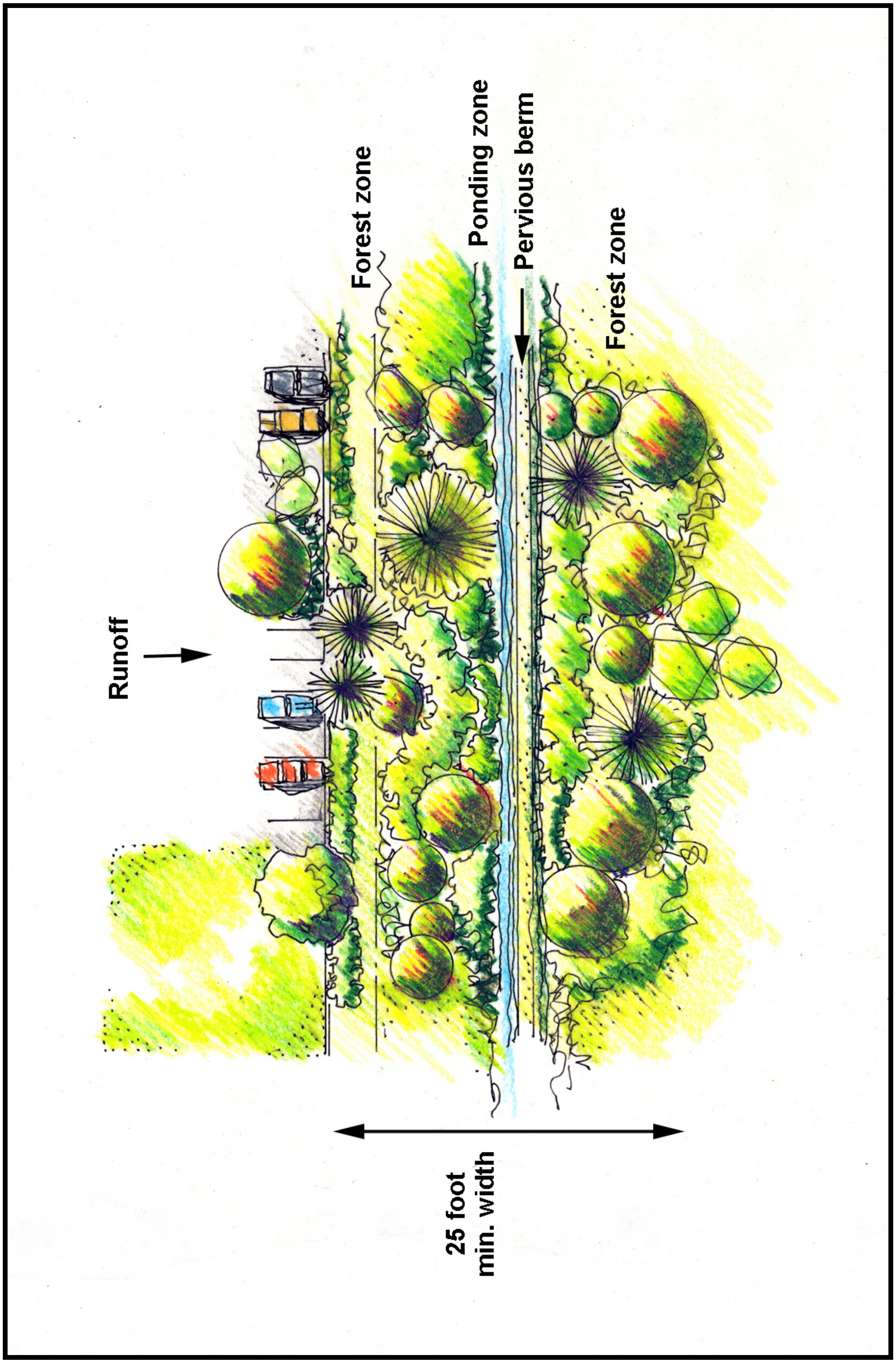

Figure 30. Forested Filter Strip plan (Graphic by Matt Arnn)

Species Selection

Existing trees should be incorporated into the design where possible. Otherwise, select a diverse mix of native species (minimum of three) that are:

- ☐ Tolerant of salt
- ☐ Tolerant of inundation (standing water in ponding zone, fluctuating water levels in forested zone).

General Planting Guidance

- ☐ Shrubs and small trees can be incorporated into the ponding zone, and larger tree species can be incorporated into the forested zone.
- ☐ Conserve existing soil, if undisturbed, and use soil amendments if site soils are compacted.
- ☐ Overplant with seedlings or whips for fast establishment and to account for mortality. Alternatively, plant larger stock at desired spacing intervals (35-50 feet for large and very large trees) using random spacing.

Maintenance

- ☐ Use mulch to retain moisture.
- ☐ Use tree shelters to protect seedlings.

Topics for Future Research

- ☐ Quantify increased pollutant removal due to trees in filter strip.

Further Resources

Center for Watershed Protection. 1996. *Design of Stormwater Filtering Systems.* Center for Watershed Protection, Ellicott City, MD.

Maryland Department of the Environment. 2000. *Maryland Stormwater Design Manual*. Maryland Department of the Environment, Baltimore, MD.

Multi-Zone Filter Strip

Description

A traditional filter strip is a grass area that is intended to treat sheet flow from adjacent impervious areas. Filter strips function by slowing runoff velocities and filtering out sediment and other pollutants, and providing some infiltration into underlying soils.

A multi-zone filter strip provides a similar function but incorporates trees and shrubs into the design. A multi-zone filter strip features several vegetative zones that provide a gradual transition from turf to forest (Figures 31 and 32). The zones include: turf, meadow, shrub, and forest. The multi-zone filter strip can be effectively designed as a transition filter zone to an existing forest area. Additional benefits provided by a multi-zone filter strip include: evapotranspiration, wildlife habitat, and infiltration promoted by macropore formation.

Multi-zone filter strips may be used:

- ☐ In linear areas such as stream buffers and transportation corridors.
- ☐ As pretreatment for a stream buffer or other stormwater treatment practice.
- ☐ Where runoff is present as sheetflow and travels over short distances (a maximum of 75 feet of impervious area, or 150 feet of pervious area).
- ☐ Where safety and visibility are concerns (e.g., next to parking lot or public area)

Design Modifications

- ☐ Use curb stops or parking stops to keep cars from driving on the grass area, if next to a parking lot.
- ☐ Use a gravel diaphragm for pretreatment.
- ☐ Minimum practice width should be 25 feet.

Species Selection

Existing trees should be incorporated where possible. Otherwise, select a minimum of three native species to plant that are:

- ☐ Tolerant of inundation
- ☐ Tolerant of salt

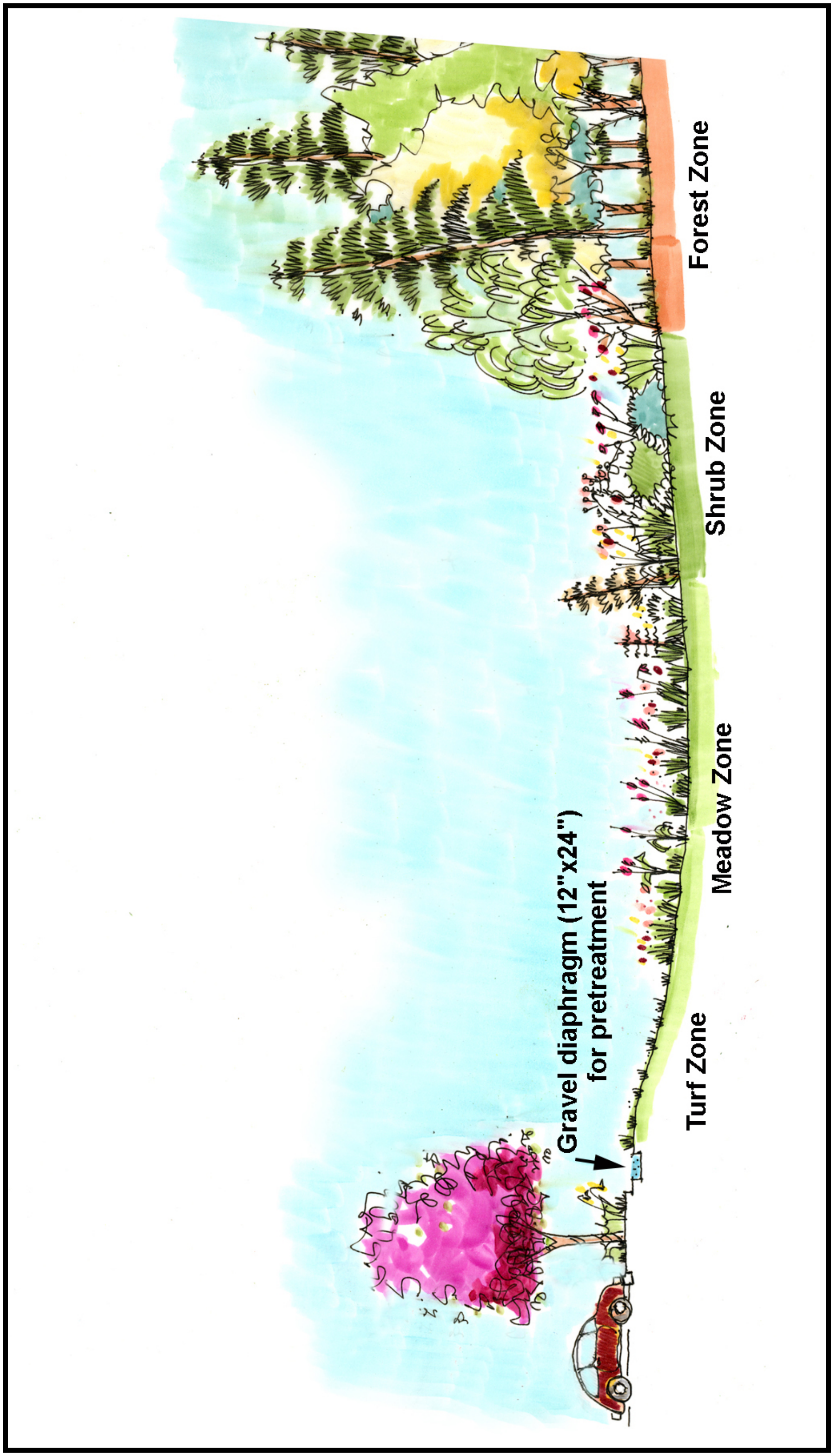

Figure 31. Multi-Zone Filter Strip profile (Graphic by Matt Arnn)

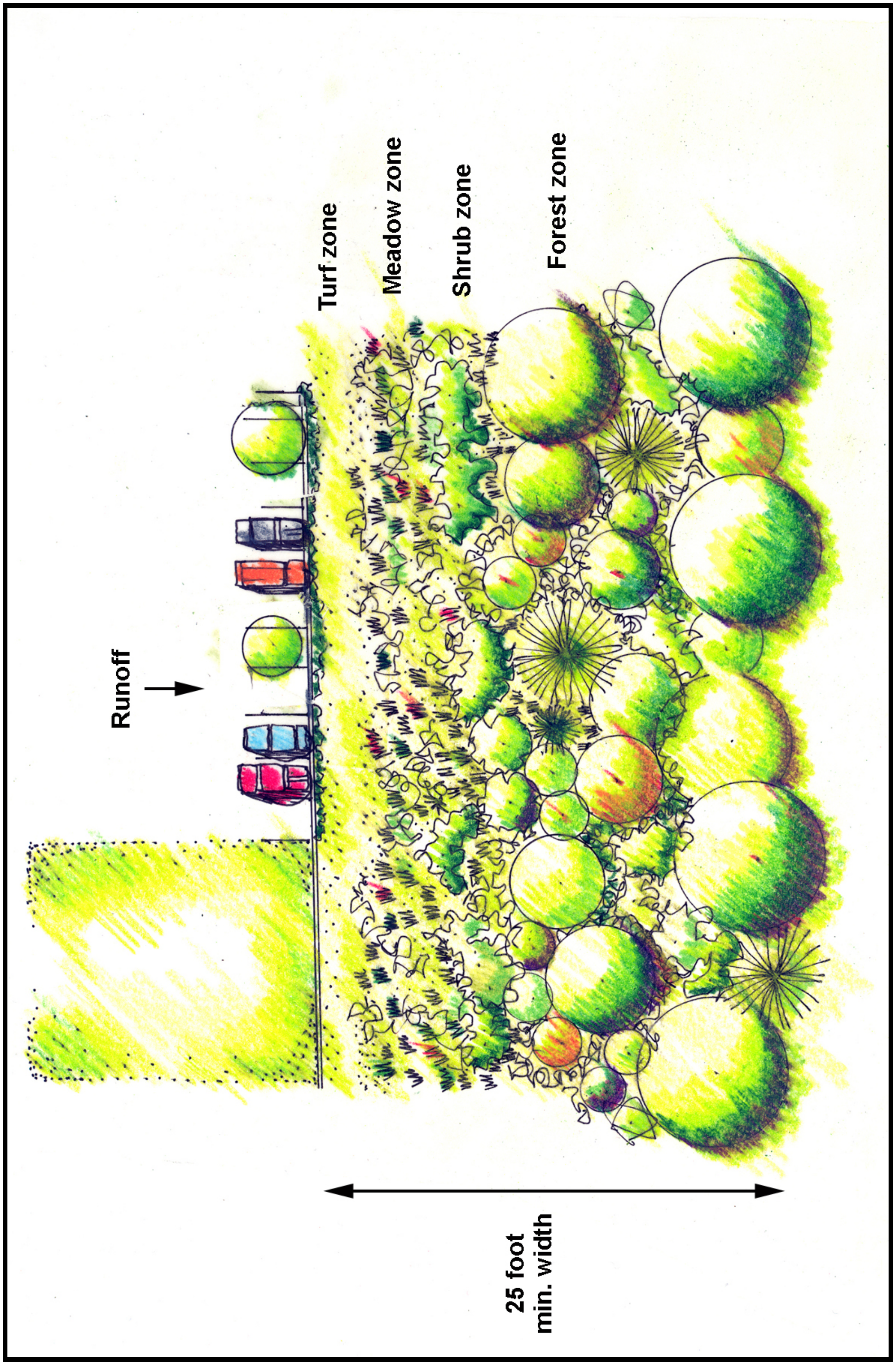

Figure 32. Multi-Zone Filter Strip plan (Graphic by Matt Arnn)

General Planting Guidance

- ☐ Plant each zone with the desired vegetation. Widths of each vegetative zone may vary. Shrub zone may ultimately become a tree zone.
- ☐ Conserve existing soil, if undisturbed, and use soil amendments if compacted.
- ☐ Overplant with seedlings or whips for fast establishment and to account for mortality, or plant larger stock at desired spacing intervals (35-50 feet for large and very large trees) using random spacing.

Maintenance

- ☐ Use mulch to retain moisture.
- ☐ Use tree shelters to protect seedlings
- ☐ Mow turf zone regularly and reseed as needed
- ☐ Mow meadow zone biannually

Topics for Future Research

- ☐ Quantify additional pollutant removal due to trees in filter strip.

Further Resources

Center for Watershed Protection. 1996. *Design of Stormwater Filtering Systems.* Center for Watershed Protection, Ellicott City, MD.

Maryland Department of the Environment. 2000. *Maryland Stormwater Design Manual*. Maryland Department of the Environment, Baltimore, MD.

Linear Stormwater Tree Pit

Description

A linear stormwater tree pit is similar to a traditional street tree pit design, but is modified so the pit accepts and treats stormwater runoff, and provides an improved planting environment for the tree. A stormwater tree pit has additional soil volume, regular irrigation and better drainage to promote tree growth, and a continuous soil trench underneath the pavement connects individual tree pits (Figures 33 and 34).

Linear stormwater tree pits are most useful for the following conditions:

- ☐ Where existing soils are very compacted or poor.
- ☐ Where open space for planting is limited (e.g., ultra urban areas) and rooting space can be provided for trees underneath pavement.
- ☐ In street tree or other linear applications (although it can be adjusted for a different application, such as clustered plantings in a courtyard).
- ☐ New development, or as a retrofit of existing development, when done in conjunction with repair of underground utilities or streetscaping project that requires sidewalk excavation.

Design Modifications

- ☐ Stormwater is directed from rooftops to tree pits using sunken roof leaders covered with grates. An alternative is to use curb cuts to direct street runoff to the pits for added water quality benefits. In this case, a filter screen or cleanout device must be provided to capture trash and litter.
- ☐ An underdrain is installed under tree pits that connects to either existing storm drain inlets or the storm sewer. The underdrain is surrounded by a layer of gravel to provide some filtering. A variation is to add a gravel base under the underdrain to allow some infiltration.
- ☐ Trees are planted within a linear trench with filter media to allow filtering of stormwater and shared rooting space for trees underneath pavement.
- ☐ Reinforced concrete sidewalks should have wide surface opening for to accommodate the mature size of tree (sidewalks will be cantilevered over planting holes).
- ☐ Consider use of structural soils under pavement, which allows tree roots to grow in it and also meet engineering specifications (see Bassuk, et al, no date and Part 3 of this manual for more information).

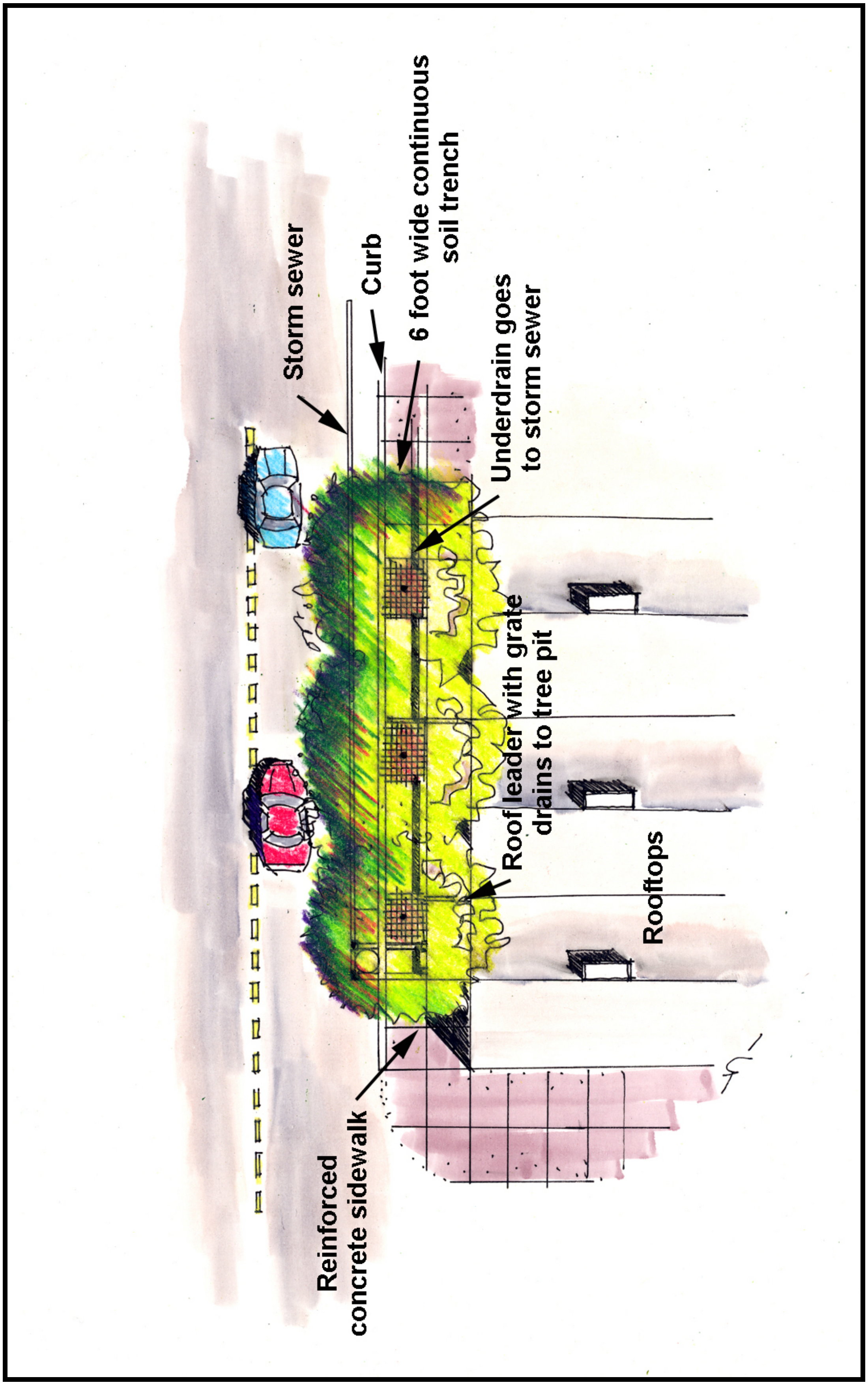

Figure 33. Linear Stormwater Tree Pit profile (Graphic by Matt Arnn)

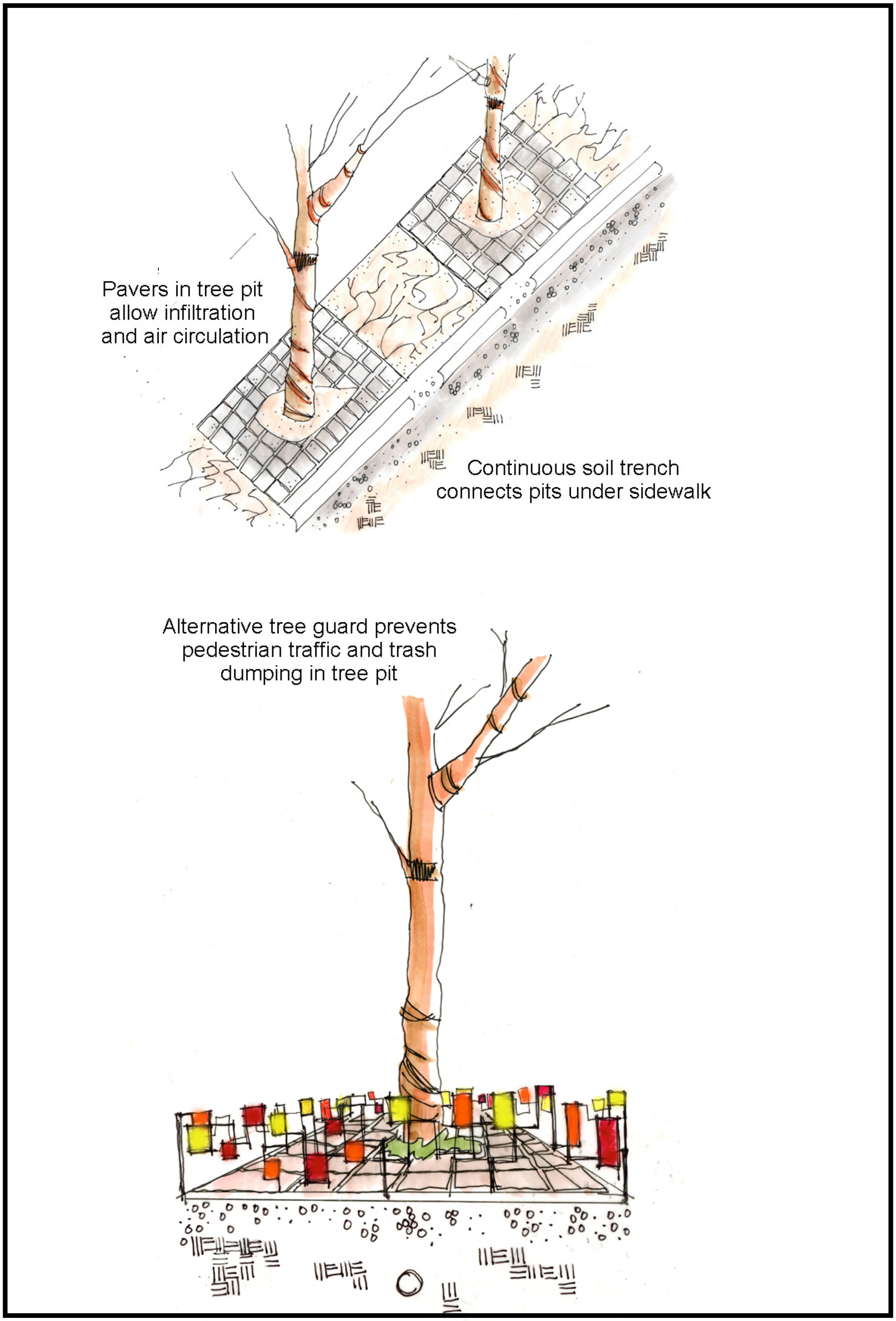

Figure 34. Tree Pit protection (Graphic by Matt Arnn)

Species Selection

Species selection is critical in stormwater tree pits because unmodified site conditions are often highly stressful to healthy tree growth. A mix of hardy species should be selected that are adapted to the following soil and site conditions:

- ☐ Tolerant of poor, compacted soils
- ☐ Tolerant of salt
- ☐ Tolerant of urban pollutants
- ☐ Tolerant of inundation
- ☐ Tolerant of drought
- ☐ Wide spreading canopy

General Planting Guidance

- ☐ Excavate a planting trench 4 feet deep and a minimum of 6 feet wide. The volume for each tree should be adequate for the mature size of the tree, assuming some shared soil volume. Backfill trench with filter media. The top of the planting trench should be slightly below grade to allow space for circulation.
- ☐ Plant at desired spacing intervals.
- ☐ Install concrete bollards, fencing or other structures (see Figure 34) to prevent pedestrians from stepping in tree pit (tree grates are not recommended since they can damage the tree if not adjusted as it grows).

Maintenance

- ☐ Use mulch to retain moisture.

Topics for Future Research

- ☐ Need better method to prevent use of tree pits as trash cans.
- ☐ Develop guidance on sizing and volume of tree pits so as not to direct too much water into pits.

Further Resources

Bassuk, N., J. Grabosky, P. Trowbridge, and J. Urban. (No Date). *Structural Soil: An Innovative Medium Under pavement that Improves Street Tree Vigor*. Urban Horticulture Institute, Cornell University, Ithaca, NY. Available online: http://www.hort.cornell.edu/department/faculty/bassuk/uhi/outreach/csc/article.html

Hammerschlag, R. S. and J.L. Sherald. 1985. Traditional and Expanded Tree Pit Concepts. In: *METRIA 5: Selecting and Preparing Sites for Urban Trees.* Proceedings of the Fifth Conference of the Metropolitan Tree Improvement Alliance. The Pennsylvania State University, University Park, PA.

Hoke, J. R., Jr., Ed. 2000. *Architectural Graphic Standards*. *10th ed*. John Wiley and Sons, Inc New York, NY.

Urban, J. 1998. Room to Grow. *Treelink* 11:1-4.

CHAPTER 4: TREE PLANTING ALONG STREETS AND IN PARKING LOTS

This chapter provides guidance on planting trees along local streets and within parking lots at new development sites and presents this guidance in fact sheet format. Pervious portions of a development site that make good candidates for tree planting and are often overlooked include: local road rights-of-way, landscaped islands in cul-de-sacs or traffic circles, and parking lots. Many local landscaping ordinances often require developers to plant street trees or to landscape a certain percentage of every parking lot.

One of the most common features of highly desirable neighborhoods is the presence of large street trees that form a canopy over the road. Many newer developments either do not incorporate street trees or use small, ornamental trees or other types of vegetation within the planting strip (Figure 35). Street trees are traditionally planted in a linear fashion along either side of the road. Alternatives to this design include: planting trees in clusters along the side of the road (Figure 36), planting trees within median strips (Figure 37) or planting trees in islands located in cul-de-sacs or traffic circles (Figure 38). Each planting area has specific considerations for incorporating trees to ensure adequate space is provided and to address common concerns about visibility and conflicts with overhead wires or pavement (Figure 39).

Figure 35. Development with no street trees (top) and mature trees that form a canopy over the street (bottom)

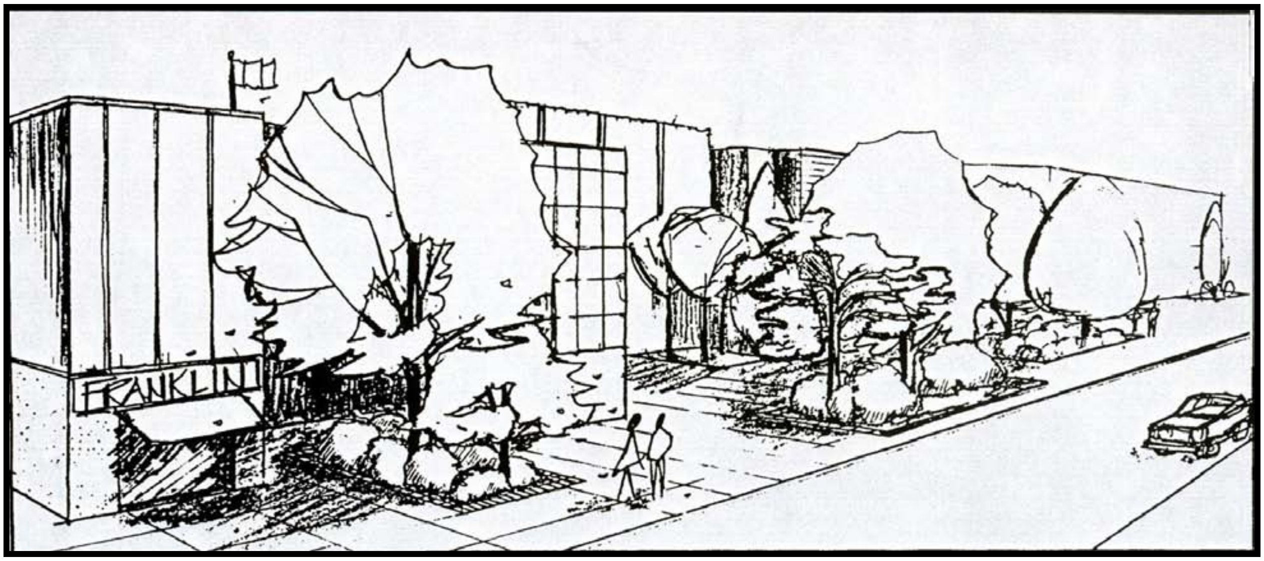

Figure 36. Non-linear street tree plantings (Source: Meyer, no date)

Figure 37. Excessively wide road with little vegetation (left) and trees planted in median strip provide shade, slow traffic and make the street more attractive (right)

Figure 38. Typical cul-de-sac with no vegetation (left) and trees planted in cul-de-sac island (right)

Figure 39. Trees that are planted in holes that are too small may eventually crack nearby pavement (photo on left by Ed Gilman)

Trees in parking lots reduce the urban heat island effect, remove pollutants, provide shade and habitat for wildlife and increase the aesthetic value of the parking lot. However, many commercial parking lots use a ‘cookie cutter’ design that does not incorporate trees (Figure 40). However, a parking lot can be a very harsh climate for a tree, so several important design considerations are necessary.

Figure 40. Parking lot with no landscaping (left) and a double-wide interior planting strip that allows trees to share rooting space (right, photo by Ed Gilman)

Planting guidance for trees along streets and in parking lots is presented in the remainder of this chapter in fact sheet format. Each fact sheet contains the following sections:

Description – brief description of the planting concept.

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 in the Species Selection, Site Preparation, Planting Guidance or Maintenance sections.

Species Selection – desirable characteristics of species to be planted at the site. Part 3 of this manual includes an urban tree database with tree and shrub species and their characteristics.

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 Stormwater Treatment – potential for integrating trees and stormwater treatment practices in this location.

Further Resources – resources for additional information.

Planting Trees Along Local Roads

Description

Local roads offer three areas to incorporate trees: the buffer, the median strip, and landscaped islands in cul-de-sacs or traffic circles (Figures 41 and 42). The buffer consists of the area between the edge of the road pavement and adjacent private property. The median strip is the area between opposing traffic lanes. Cul-de-sacs are large diameter bulbs at the end of streets to enable vehicles to turn around. They often involve large areas of pavement, but present a good opportunity to plant trees in neighborhoods.

Trees planted along local roads can reduce air pollution and stormwater runoff, provide habitat for wildlife such as birds, provide shade for pedestrians, reduce air temperatures, stabilize the soil, provide a visual screen and barrier from noise and highway fumes, and make for a visually pleasing environment for drivers and homeowners.

Pre-Planting Considerations

Before planting trees along local roads, designers need to address some important questions:

- ☐ How to provide clear lines of sight, safe travel surfaces and overhead clearance for pedestrians and vehicles?
- ☐ How to prevent compaction of planting area soils by construction and foot traffic?
- ☐ How to resolve potential conflicts between trees and utilities, pavement and lighting?
- ☐ How to make the road corridor more attractive with plantings?
- ☐ How to reduce tree exposure to auto emissions, polluted runoff, wind and drought?
- ☐ How to provide enough future soil volume for healthy tree growth?
- ☐ How to prevent damage to trees from cars?
- ☐ How to address concerns about increased tree maintenance, damage to cars from trees (e.g., sap, branches) and roadway snow removal/storage?

Species Selection

Species selection is very important in the road corridor, because of the many potential urban stressors associated with roadway planting. A diverse mix of hardy species should be selected that are adapted to soil and site conditions and are tolerant of the following:

- ☐ Drought
- ☐ Poor or compacted soils
- ☐ Inundation (if used for stormwater treatment)
- ☐ Urban pollutants (oil and grease, metals, chloride)

In addition, tree species should be selected that: do not produce abundant fruits, nuts, or leaf litter; have fall color, spring flowers, or some other aesthetic benefit; and can be limbed up to six feet to provide pedestrian and vehicle access underneath.

Site Preparation

- ☐ Clean up trash
- ☐ Improve soil draining by tilling and adding compost
- ☐ Remove invasive plants if present

General Planting Guidance

- ☐ Provide adequate soil volume, preferably by having a six-foot wide minimum planting strip, or locating sidewalks between the buffer and street to allow more rooting space for the trees in adjacent property
- ☐ Provide adequate setbacks from utilities, signs, lighting and pavement
- ☐ Use tree clusters as an alternative to linear plantings, which will provide shared rooting space
- ☐ Use structural soil under pavement to provide shared rooting space
- ☐ Use groupings of species that provide fall color, flowers, evergreen leaves, and varying heights to create an aesthetically pleasing landscape

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Maintenance

- ☐ Use mulch to retain moisture
- ☐ Plan for minimal maintenance of trees (watering may not be feasible)
- ☐ Water trees during dry periods if possible
- ☐ Have trees pruned by a qualified arborist to maintain sightlines and overhead clearance
- ☐ Monitor and control invasive species

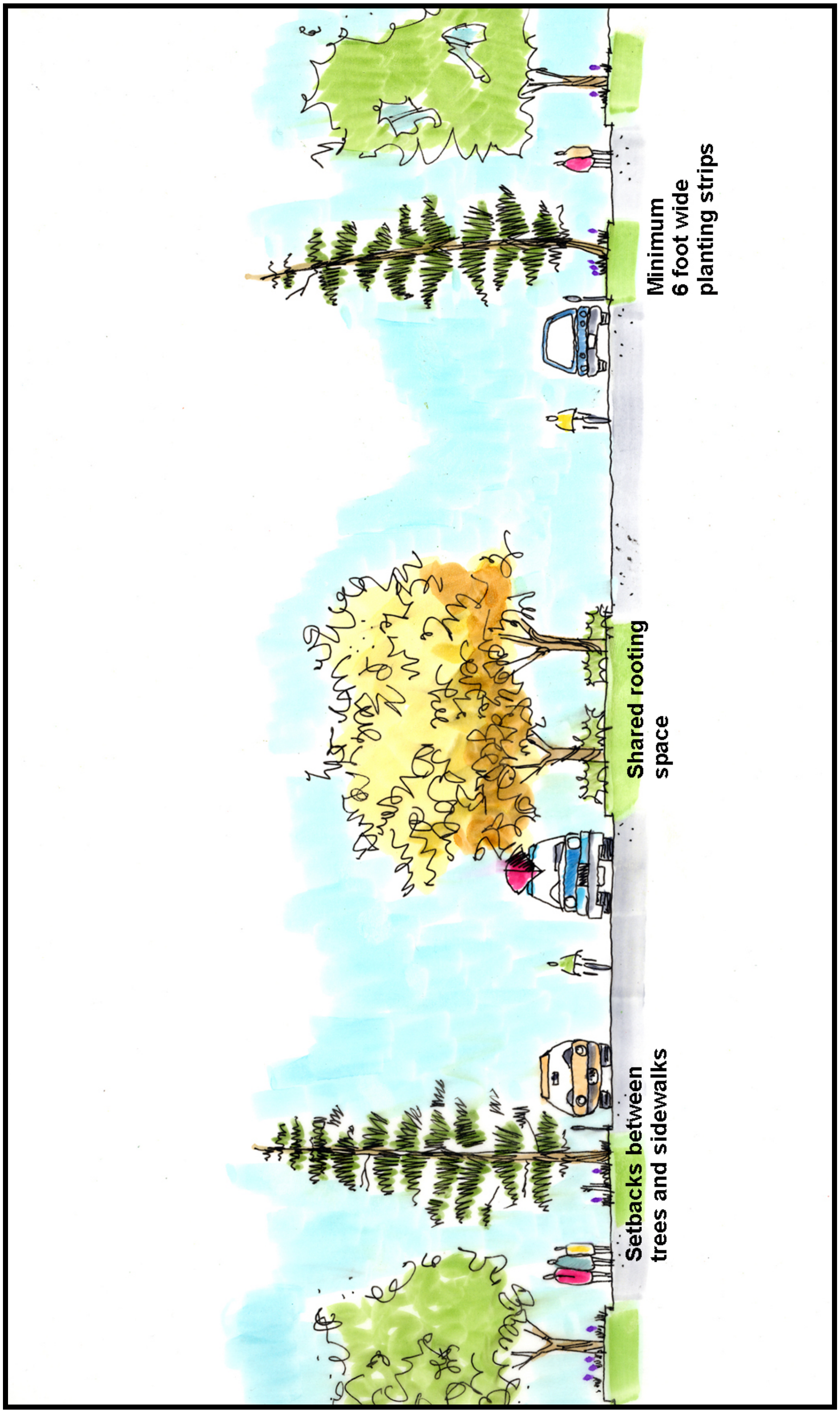

Figure 41. Planting trees along local roads – profile (Graphic by Matt Arnn)

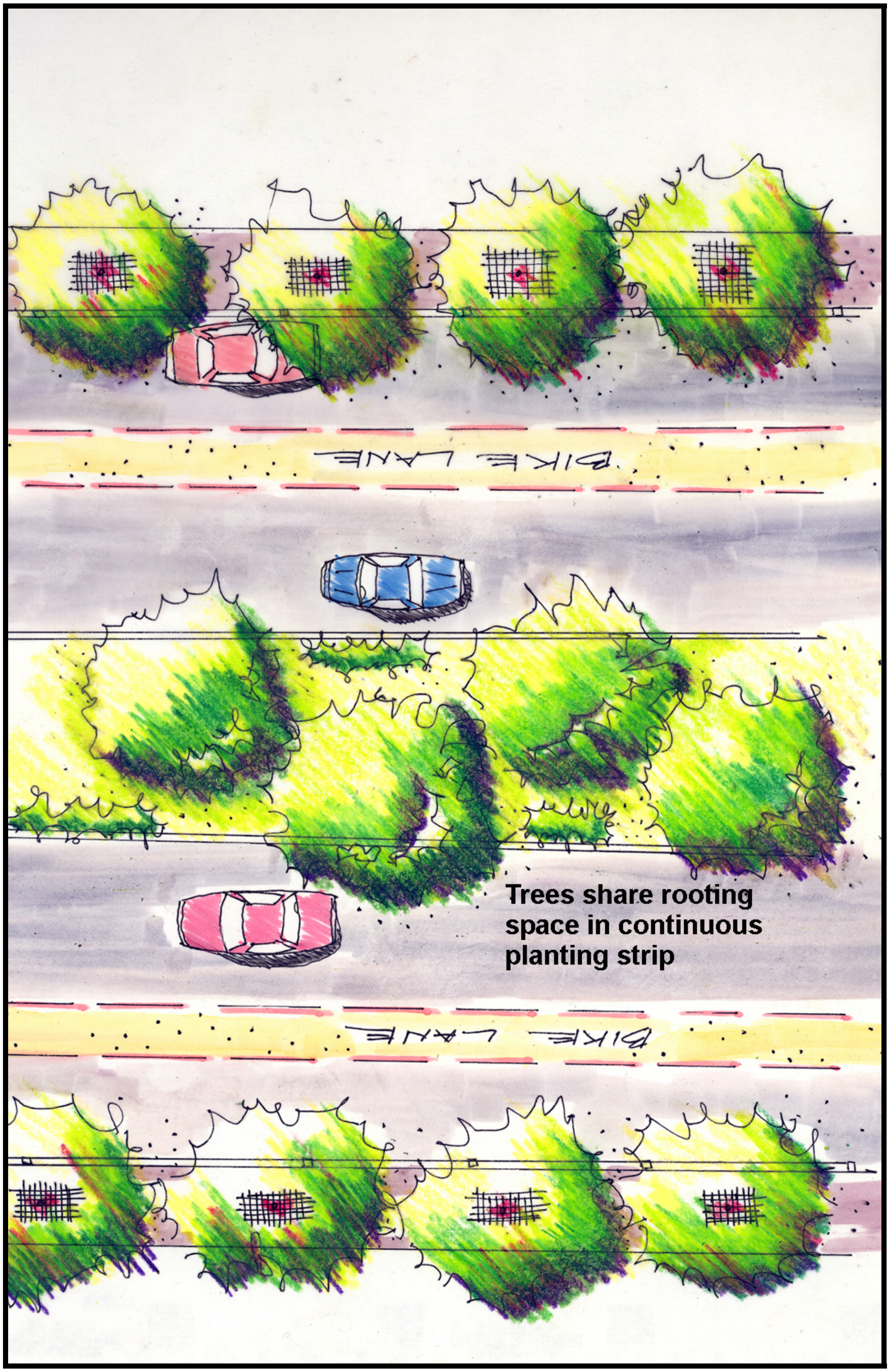

Figure 42. Planting trees along local roads – plan (Graphic by Matt Arnn)

Potential for Stormwater Treatment

Local road buffers and median strips are ideal locations to treat stormwater runoff from roads. Trees planted in these areas can be incorporated in stormwater forestry practices such as bioretention and bioinfiltration facilities, alternating side slope plantings, tree check dams, forested filter strips, multi-zone filter strips, and linear stormwater tree pits.

Trees planted in landscaped islands can be used to intercept rainwater and treat stormwater runoff from the surrounding pavement. Bioretention and bioinfiltration facilities may be well-suited to cul-de-sac islands. See Chapter 3 for more detail on stormwater forestry practices.

Further Resources

Bassuk, N., J. Grabosky, P. Trowbridge, J. Urban. (No Date). *Structural Soil: An Innovative Medium Under Pavement That Improves Street Tree Vigor*. Urban Horticulture Institute, Cornell University, Ithaca, NY. Available online: http://www.hort.cornell.edu/department/faculty/bassuk/uhi/outreach/csc/article.html

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

Georgia Forestry Commission. 2002. *Community Tree Planting and Establishment Guidelines*. Georgia Forestry Commission, Macon, GA. Available online: http://www.gfc.state.ga.us/Publications/UrbanCommunityForestry/CommunityTreePlanting.pdf

Gerhold, H. D., Wandell, W. N. and N. L Lacasse. 1993. *Street Tree Factsheets*. The Pennsylvania State University College of Agricultural Sciences, University Park, PA.

Metro. 2002. *Green Streets: Innovative Solutions for Stormwater and Stream Crossings*. Metro, Portland, OR.

Planting Trees in Parking Lots

Description

Parking lots have two distinct areas where trees can be planted - the interior and the perimeter - each of which has unique planting requirements and considerations (Figure 43). The parking lot interior can be a very harsh planting environment for trees, due to higher temperatures of the pavement, little water, exposure to wind, air pollution and potential damage from automobiles. Landscaped islands are typically used within parking lots to provide a separation between parking bays and to meet landscaping requirements. These islands may be planted with grass, trees or other vegetation and can be designed to accept stormwater. Typically, most traditional parking lot islands do not provide adequate soil volumes for trees.

Trees planted along the perimeter of a parking lot provide a screen or buffer between the lot and an adjacent land use or road. Perimeter planting areas often provide a better planting environment for trees and good opportunities for conserving existing trees during parking lot construction.

The many benefits of incorporating trees in parking lots include shade for people and cars, reduction of the urban heat island effect, interception of stormwater, improved aesthetics, improved air quality and an increase in or creation of habitat for birds.

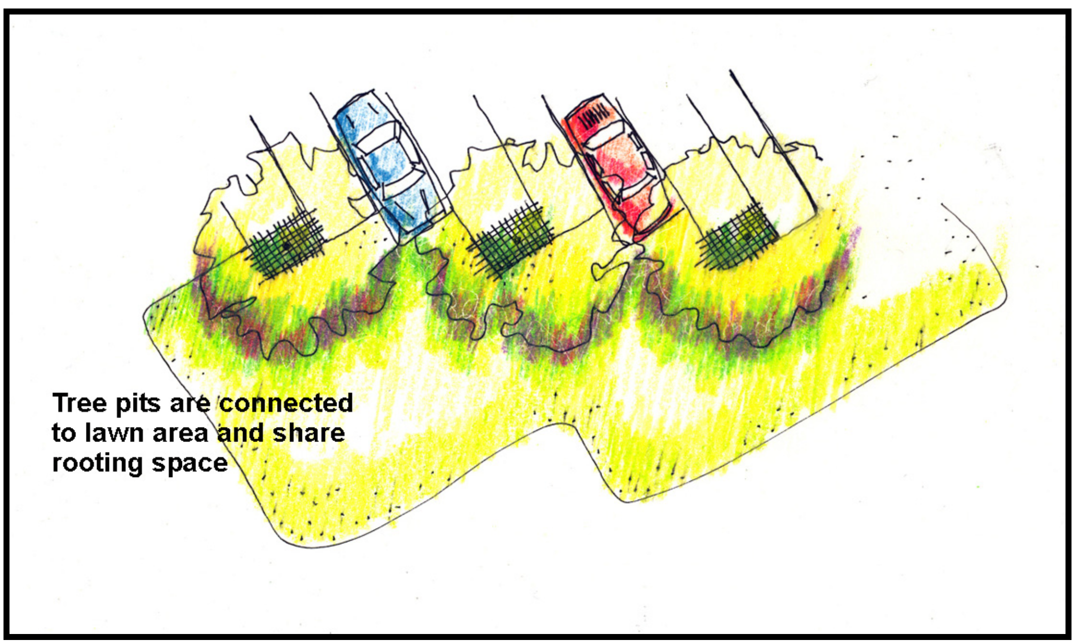

Figure 43. Planting trees in parking lots (Graphic by Matt Arnn)

Pre-Planting Considerations

Before planting trees in parking lots, designers need to address some important questions:

- ☐ How to provide clear lines of sight, safe travel surfaces and overhead clearance for movement of pedestrians and vehicles within the lot?
- ☐ How to prevent compaction of planting area soils by construction and foot traffic?
- ☐ How to resolve potential conflicts between trees and surrounding utilities, pavement and lighting?
- ☐ How to maximize canopy coverage and shading in the lot and make it more attractive with plantings?
- ☐ How to reduce exposure of trees to auto emissions, polluted runoff, wind and drought?
- ☐ How to provide adequate soil volume for trees in the confined space of a parking lot?
- ☐ How to prevent damage to trees from cars?
- ☐ How to address concerns about safety, increased maintenance due to tree litter, damage to cars from trees (e.g., sap, branches) and snow removal/storage?
- ☐ How to maximize plantings for visual screening and buffers, at the same time offering view corridors to merchants?

Species Selection

Species selection is important in urban parking lots because it is such a stressful environment. Tree species that comprise a diverse mix of hardy, native species that are adapted to soils and site conditions are needed. The following characteristics should be reviewed when selecting a parking lot tree:

- ☐ Tolerant of salt
- ☐ Tolerant of drought and extreme temperatures
- ☐ Tolerant of poor, highly compacted soils
- ☐ Tolerant of urban pollutants
- ☐ Tolerant of inundation, if used for stormwater treatment
- ☐ Does not produce abundance of fruits, nuts, or leaf litter
- ☐ Wide-spreading canopy
- ☐ Trees with a single leader trunk that can be limbed up to eight feet

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Site Preparation

- ☐ Improve soil drainage by tilling soils and adding compost

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General Planting Guidance

- ☐ Use structural soils below pavement to allow for root growth where possible
- ☐ A few great trees are better than a lot of smaller ones
- ☐ Design concave planting areas to discourage pedestrian traffic
- ☐ Provide adequate setbacks from utilities, signs, lighting and pavement
- ☐ Plant only species that are appropriate for parking lots
- ☐ Maintain appropriate setbacks from edge of planting strip or island to allow clear sight lines and reduce heat impact on trees (generally four feet)
- ☐ Maintain an adequate setback between parking stalls and trees to prevent damage from cars
- ☐ Plant ball and burlap stock (three to four inch caliper)
- ☐ Have a landscape architect design the parking lot planting plan

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Specific Planting Guidance

Interior

Use alternative planting clusters in parking lot islands that allow shared rooting space and provide additional soil volume for trees.

Employ “better site design” techniques, which include reducing the size of parking stalls to make the parking lot more efficient and to provide more room for trees (CWP, 1998)

Perimeter

Use trees to provide shade over pedestrian walkways.

Maintain a six to eight foot overhead clearance for pedestrian walkways.

When planting on steep slopes, use tree clusters and create small, earthen berms around the group to retain moisture.

When planting along a flatter slope, use linear spacing for safety and functionality

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Maintenance

- ☐ Use mulch to retain moisture
- ☐ Plan for minimal maintenance (watering may not be feasible)
- ☐ Have trees pruned by a qualified arborist to maintain sight lines and overhead clearance
- ☐ Monitor and control invasive species

Potential for Stormwater Treatment

Ordinances usually require developers to landscape a minimum percentage of parking lot interiors. When properly built, these landscaped areas can double as stormwater treatment facilities, which can result in cost savings for the developer. Stormwater forestry practices for parking lots include:

- ☐ Bioretention/bioinfiltration; alternating side slope plantings or tree check dams; linear stormwater tree pits in parking lot interiors
- ☐ Bioretention/bioinfiltration; forested filter strip and multi-zone filter strips in parking lot perimeters

See Chapter 3 for more detail on stormwater forestry practices.

Further Resources

Appleton, B., Horsley, J., Harris, V., Eaton, G., Fox, L., Orband, J., and C Hoysa. 2002. *Trees for Parking Lots and Paved Areas*. Trees for Problem Landscape Sites, Publication No. 430-028. Virginia Cooperative Extension, Blacksburg, VA. Available online: http://www.ext.vt.edu/pubs/trees/430-028/430-028.html

Center for Urban Forest Research (CUFR). 2002. *Fact Sheet #3: Making Parking Lots More Tree Friendly*. Center for Urban Forest Research, USDA Forest Service Pacific Southwest Research Station, Davis, CA. Available online: http://cufr.ucdavis.edu/products/CUFR_181_UFfactsheet3.pdf

Center for Urban Forest Research (CUFR). 2002. "*Where are all the Cool Parking Lots?*" Center for Urban Forest Research, USDA Forest Service Pacific Southwest Research Station, Davis, CA. Available online: http://cufr.ucdavis.edu/products/3/cufr_151.pdf

Center for Watershed Protection (CWP). 1998. Better Site Design: A Handbook for Changing Development Rules in Your Community. Center for Watershed Protection, Ellicott City, MD.

City of Sacramento. 2003. *Parking Lot Tree Shading Design and Maintenance Guidelines*. City of Sacramento, CA.

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

Georgia Forestry Commission. 2002. *Community Tree Planting and Establishment Guidelines*. Georgia Forestry Commission, Macon, GA. Available online: http://www.gfc.state.ga.us/Publications/UrbanCommunityForestry/CommunityTreePlanting.pdf

REFERENCES

Akbari, H., S. Davis, S. Dorsano, J. Huang, and S. Winnett, Eds. 1992. *Cooling Our Communities: A Guidebook on Tree Planting and Light-Colored Surfacing*. 22P-2001. U.S. EPA, Washington, DC.

Anderson, L.M., and H. K. Cordell. 1988. Influence of trees on residential property values in Athens, Georgia: a survey based on actual sales prices. *Landscape and Urban Planning* 15: 1-2,153-164.

Appleton, B., Horsley, J., Harris, V., Eaton, G., Fox, L., Orband, J., and C Hoysa. 2002. *Trees for Parking Lots and Paved Areas*. Trees for Problem Landscape Sites, Publication No. 430-028. Virginia Cooperative Extension, Blacksburg, VA. Available online: http://www.ext.vt.edu/pubs/trees/430-028/430-028.html

Arendt, R. G. 1996. *Conservation Design for Subdivisions. A Practical Guide to Creating Open Space Networks*. Island Press, Washington, DC.

Bassuk, N., Grabosky, J., Trowbridge, P. and J. Urban. (No Date). *Structural Soil: An Innovative Medium Under Pavement That Improves Street Tree Vigor*. Urban Horticulture Institute, Cornell University, Ithaca, NY. Available online: http://www.hort.cornell.edu/department/faculty/bassuk/uhi/outreach/csc/article.html

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

Center for Urban Forest Research (CUFR). 2002. *Fact Sheet #3: Making Parking Lots More Tree Friendly*. Center for Urban Forest Research, USDA Forest Service Pacific Southwest Research Station, Davis, CA. Available online: http://cufr.ucdavis.edu/products/CUFR_181_UFfactsheet3.pdf

Center for Urban Forest Research (CUFR). 2002. "*Where are all the Cool Parking Lots?*" Center for Urban Forest Research, USDA Forest Service Pacific Southwest Research Station, Davis, CA. Available online: http://cufr.ucdavis.edu/products/3/cufr_151.pdf

Center for Urban Forest Research (CUFR). 2001. *Fact Sheet #1: Benefits of the Urban Forest*. Center for Urban Forest Research, USDA Forest Service Pacific Southwest Research Station, Davis, CA. Available online: http://cufr.ucdavis.edu/products/cufr_179_UFfactsheet1.pdf

Center for Watershed Protection (CWP). 2003. *Impacts of Impervious Cover on Aquatic Systems*. Watershed Protection Research Monograph No. 1. Center for Watershed Protection, Ellicott City, MD.

Center for Watershed Protection (CWP). 1998. *Better Site Design: A Handbook for Changing Development Rules in Your Community.* Center for Watershed Protection, Ellicott City, MD.

Center for Watershed Protection (CWP). 1996. *Design of Stormwater Filtering Systems.* Center for Watershed Protection, Ellicott City, MD.

City of Portland, OR. 2004. Stormwater Management Manual. City of Portland, Bureau of Environmental Services, Portland, OR.

City of Sacramento. 2003. *Parking Lot Tree Shading Design and Maintenance Guidelines*. City of Sacramento, CA.

Coder, K. 1999. *Drought Damage to Trees*. Warnell School of Forest Resources, University of Georgia, Athens, GA. Available online: http://www.forestry.uga.edu/warnell/service/library/for99-010/index.html.

Coder, K. 1996. *Identified Benefits of Community Trees and Forests*. University of Georgia, Athens, GA. Available online: http://www.scenicflorida.org/lsctreebenefits.html.

Coder, K., 1995. Tree quality BMPs for developing wooded areas and protecting residual trees. In: *Trees and Building Sites,* ed. Watson, G. W., and Neely, D., 1995. International Society of Arboriculture, Champaign, IL.

Coder, K. 1994. *Flood Damage to Trees*. Warnell School of Forest Resources, University of Georgia, Athens, GA. Available online: http://www.forestry.uga.edu/warnell/service/library/for94-061/index.html.

Cornell University. 2004. *Conducting a Street Tree Inventory*. Department of Horticulture, Cornell University, Ithaca, NY. Available online: http://www.hort.cornell.edu/commfor/inventory/index.html

Correll, M., Lillydahl, J., and L. Singell. 1978. The Effects of Greenbelts on Residential Property Values: Some Findings on the Political Economy of Open Space. *Land Economics* 54:207-217.

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

Craul, P. J. No Date. *Urban Soils*. SUNY College of Environmental Science and Forestry, Syracuse, NY. Available online: http://www.ces.ncsu.edu/fletcher/programs/nursery/metria/metria5/m57.pdf

Ferguson, B. K. 1994. *Stormwater Infiltration*. CRC Press, Inc, Boca Raton, FL.

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

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

Georgia Forestry Commission (GFC). 2002. *Community Tree Planting and Establishment Guidelines*. Georgia Forestry Commission, Macon, GA. Available online: http://www.gfc.state.ga.us/Publications/UrbanCommunityForestry/CommunityTreePlanting.pdf

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

Gerhold, H. D., Wandell, W. N. and N. L Lacasse. 1993. *Street Tree Factsheets*. The Pennsylvania State University College of Agricultural Sciences, University Park, PA.

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

Hammerschlag, R. S. and J.L. Sherald. 1985. Traditional and Expanded Tree Pit Concepts. In: *METRIA 5: Selecting and Preparing Sites for Urban Trees.* Proceedings of the Fifth Conference of the Metropolitan Tree Improvement Alliance. The Pennsylvania State University, University Park, PA.

Harris, R.W. 1992. *Arboriculture: Integrated Management of Landscape Trees, Shrubs, and Vines*. Prentice Hall, Englewood Cliffs, NJ.

Heat Island Group. 1996. *Working to Cool Urban Heat Islands.* Berkeley National Laboratory, Berkeley, CA.

Heisler, G. M. 1986. Energy Savings with Trees. *Journal of Arboriculture* 12:113-124.

Heisler, G. M. 1989. *Site Design and Microclimate Research*. USDA Forest Service, Northeast Forest Experiment Station, University Park, PA.

Hoke, J. R., Jr., Ed. 2000. *Architectural Graphic Standards. 10th ed*. John Wiley and Sons, Inc., New York, NY.

Johnson, G. R. 2005. *Protecting Trees from Construction Damage: A Homeowner's Guide*. Regents of the University of Minnesota, St. Paul, MN. Available online: http://www.extension.umn.edu/distribution/housingandclothing/DK6135.html

Kitchen, J., and W. Hendon. 1967. Land Values Adjacent to an Urban Neighborhood Park. *Land Economics* 43:357-360.

Licht, L. A. 1990. Poplar Tree Roots for Water Quality Improvement. In *Proceedings of National Conference on Enhancing State's Lake Management Programs*. U.S. EPA, Chicago, IL.

Maryland Department of Natural Resources Forest Service (MD DNR). No date. *Maryland's Forests: A Health Report.* Maryland Department of Natural Resources, Annapolis, MD. Available online: www.dnr.state.md.us/forests/healthreport

Maryland Department of the Environment. 2000. *Maryland Stormwater Design Manual*. Maryland Department of the Environment, Baltimore, MD.

Maryland National Capital Parks and Planning Commission (MNCPPC). 1992. *Trees. Approved Technical Manual.* Maryland National Capital Parks and Planning Commission, Montgomery County, MD. Available at: http://www.mc-mncppc.org/environment/forest/trees/detail_trees.pdf

McPherson, E. G. 1998. Shade trees and parking lots. *Arid Zone Times* February:1-2.

Metro. 2002. Green Streets. *Innovative Solutions for Stormwater and Stream Crossings*. Metro, Portland, OR.

Meyer, P.W. No Date. *Alternatives to Linear Street Tree Plantings*. Morris Arboretum of the University of Pennsylvania, Philadelphia, PA.

Minnesota Department of Natural Resources (MN DNR). 2000. *Conserving Wooded Areas in Developing Communities. BMPs in Minnesota.* Minnesota Department of Natural Resources, St. Paul, MN. Available online: http://www.dnr.state.mn.us/forestry/urban/bmps.html

Morales, D.J. 1980. The Contribution of Trees to Residential Property Value. *Journal of Arboriculture* 6:305-308.

Morales, D.J., Micha, F.R, and R. L. Weber. 1983. Two Methods of Valuating Trees on Residential Sites. *Journal of Arboriculture*.9:21-24.

More, T.A., Allen, P.G., and T. H. Stevens. 1983. Economic valuation of urban open-space resources. In: *America's Hardwood Forests--Opportunities Unlimited: Convention of the Society of American Foresters; 1982 September 19-22*. SAF Publication 83-04. Society of American Foresters, Bethesda, MD.

Nowak, D.J., Kuroda, M., and D.E. Crane. 2004. Tree Mortality Rates and Tree Population Projections in Baltimore, Maryland, USA. *Urban Forestry and Urban Greening* 2:139-147. Available online:

http://www.fs.fed.us/ne/newtown_square/publications/other_publishers/OCR/ne_2004nowak01.pdf

Parker, J. H. 1983. Landscaping to Reduce the Energy Used in Cooling Buildings. *Journal of Forestry* 81:82-83.

Pennsylvania State University (PSU). 1999. *A Guide to Preserving Trees in Development Projects.* Penn State College of Agricultural Sciences Cooperative Extension, University Park, PA.

Prince George's County Department of Environmental Resources Program and Planning Division (PG County DER). 2001. *Bioretention Manual*. Prince George's County, Upper Marlboro, MD.

Schueler, T. R. 1992. *Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetlands in the Mid-Atlantic Region*. Metropolitan Washington Council of Governments, Washington, D.C.

Schueler, T. R. 1995. *Site Planning for Urban Stream Protection*. Center for Watershed Protection, Ellicott City, MD.

Schueler, T. R. 2000. The Economics of Watershed Protection. Article 30 in *The Practice of Watershed Protection*, eds T.R. Schueler and H. K. Holland. Center for Watershed Protection, Ellicott City, MD.

Scott K.I., Simpson, J. R., and E.G. McPherson. 1998. Green Parking Lots: Can Trees Improve Air Quality? *California Urban Forests Council Newsletter* Spring 1998:1-2. Available online: http://cufr.ucdavis.edu/products/cufr_71_SK98_77.PDF.

Shaw, D. and R. Schmidt. 2003. *Plants for Stormwater Design*. *Species Selection for the Upper Midwest.* Minnesota Pollution Control Agency, St. Paul, MN.

Stormcenter Communications, Inc. 2003. A Recipe for Ozone. *Envirocast Weather and Watershed Newsletter* 1(11). Available online: http://www.stormcenter.com/envirocast/2003-09-25/feature.html

Sullivan, W. C. and F. E. Kuo. 1996. *Do trees strengthen urban communities, reduce domestic violence?* Technology Bulletin. R8-FR56. USDA Forest Service, Southern Region, Southern Station and Northeastern Area, Atlanta, GA.

Trees Atlanta. No Date. *Facts*. Trees Atlanta, Atlanta, GA. Available online: http://www.treesatlanta.org/facts.html

Ulrich, P.S. 1984. View Through a Window May Influence Recovery from Surgery. *Science*. 224:420-421.

University of Washington. 1998. *Trees in Business Districts: Positive Effects on Consumer Behavior!* Center for Urban Horticulture, University of Washington, College of Forest Resources, Seattle, WA.

Urban, J. 1998. Room to Grow. *Treelink* 11:1-4.

U.S. Army Corps of Engineers (USACE). 1989. *Retaining and Flood Walls.* Engineer Manual No. 1110-2-2502. U.S. Army Corps of Engineers, Washington, DC.

U.S. Environmental Protection Agency (EPA). 1998. *A Citizen's Guide to Phytoremediation*. EPA 542-F-98-011. U.S. EPA, Office of Solid Waste and Emergency Response, Washington, DC.

USDA Forest Service. 1998. *Volunteer Training Manual*. USDA Forest Service, Northeast Center for Urban and Community Forestry, Amherst, MA. Available online: http://www.umass.edu/urbantree/volmanual.pdf

Weyerhaeuser Company. 1989. *The Value of Landscaping.* Weyerhaeuser Nursery Products Division, Tacoma, WA.

Wildlife Habitat Enhancement Council. 1992. *The Economic Benefits of Wildlife Habitat Enhancement on Corporate Lands*. Wildlife Habitat Enhancement Council, Silver Spring, MD.

Winer, R. W. 2000. *Pollutant Removal Database: 2nd Edition*. Center for Watershed Protection, Ellicott City, MD.

Yu, S., Barnes, S., and V. Gedde, 1993. *Testing of best management practices for controlling highway runoff.* FWHA/VA 93-R16. Virginia Transportation Research Council, Charlottesville, VA.

APPENDIX A. MARYLAND FOREST STAND DELINEATION

This appendix contains field sheets for use in delineating forest stands as part of Maryland's Forest Conservation Act requirements. The field sheets and guidance are taken directly from the Maryland Forest Conservation Manual. For further guidance on conducting a Forest Stand Delineation, see Greenfeld, et al (1991).

Figure D-1 **Forest Conservation Worksheet**

Input Data

A. TOTAL SITE AREA:____________________
B. AREA WITHIN 100 YEAR FLOODPLAIN:________________
C. AREA OF AGRICULTURAL LAND (no change in status):_________
D. *NET TRACT AREA (A-B-C):*________________________

E. LAND USE CATEGORY:_______________________________________
F. AFFORESTATION THRESHOLD:____________________
G. CONSERVATION THRESHOLD:_____________________

H. CURRENT FOREST COVER:______________________
I. FOREST AREA ABOVE AFFORESTATION THRESHOLD:__________
J. FOREST AREA ABOVE CONSERVATION THRESHOLD:__________

K. **ABOVE** CONSERVATION THRESHOLDTO BE CLEARED:________________________
L. **BELOW** CONSERVATION THRESHOLD TO BE CLEARED:_______
M. TOTAL FORESTED AREA TO BE CLEARED:_______
N. FORESTED AREA **ABOVE** CONSERVATION THRESHOLD TO BE SAVED:

Calculations

Break-Even Point:
O. ACRES ABOVE CONSERVATION THRESHOLD TO BE RETAINED FOR NO REQUIRED REFORESTATION: J * 20 % = ________ ACRES

Afforestation Requirement:
P. FORESTED ACRES REQUIRED: D * F = ________
Q. ACRES TO BE AFFORESTED: P - H = _________

Reforestation Requirement:
R. ACRES CLEARED ABOVE THRESHOLD: K * 1/4 = ______
S. ACRES CLEARED BELOW THRESHOLD: L * 2 = ______
T. REFORESTATION CREDIT: N X 1.25 = _______
U. *TOTAL REFORESTATION REQUIREMENT:* R + S - T = ________ ACRES

Table D-1: Field Sampling Data Sheet

Property Name:
Stand #
Plot #
Prepared by:
Date:

	Size Class of Trees Within the Sample Plot				
Tree Species (note dominant and co-dominant species)	Number of Trees 2-6" dbh	Number of Trees 6-10" dbh	Number of Trees 11-17" dbh	Number of Trees 18-29" dbh	Number of Trees >30" dbh
Number of Trees per size class					
List of understory species					
Basal Area					
Number of Dead Trees per plot					
Comments					

Table D - 2 Explanation of Terms

Forest Stand Information

Stand # - divide the vegetative cover into different stands depending on species groups, size groups, cover types, etc.

Acres - measure the acreage in each separate stand and open areas. Round off to the nearest 1/20 acre.

Species - list the four or five most common, dominant and co-dominant species tallied.

Size Class - use the following size classes: 2" to 6 " dbh, 7" to 10" dbh, 11" to 17" dbh, 18" to 29" dbh, and grater than 30" dbh.

Basal Area - this is a density measurement and should be expressed on a per acre basis for each stand.

Number of Trees - count all trees 2" dbh or greater occurring on the plot.

Number of Tree Species - count the total number of trees species occurring on the plot.

Number of Dead Trees - count the total number of dead trees occurring on the plot.

Understory Species - record the 3 to 5 most commonly occurring understory species on the plot.

Forest Cover Type - use the Society of American Foresters classification, the Maryland forest Association Species List and the species tallied on site to determine this.

Forest Structure Data Sheet

Number of Understory Shrubs - count the total number of shrubs occurring on the plot.

Percent Canopy Closure - estimate the canopy closure using the method described.

Percent Understory Herbaceous Ground Cover - estimate the herbaceous ground cover using the method described.

Percent Down Woody Debris (greater than 2" in diameter) - estimate the amount of dead and down woody debris on the ground using the method described.

Figure D-2 Techniques for Forest Structure Data Collection

To measure canopy coverage, herbaceous coverage, dead and downed woody material present and exotic species, it will be necessary to sample in the following way:

1) Construct a sampling tube from a paper towel or toilet paper roll. Attach wires or string on one end of the tube in the configuration of a cross with four evenly spaced openings (see a below).

2) Select 1 random sampling point within **each** forest stand. To do this, construct an circular sampling plot of 1/10 acre. Take samples from 4 points around the circle and one within the circle (see b below).

3) Walk to each sample point and look through the sampling tube at each sample point.

   a) For canopy coverage, record "yes" or "no" for green seen through the tube when pointed up (tube must be held vertically; count only trees 7"DBH and larger.).

   b) For herbaceous coverage, record "yes" or "no" for green seen through the tube when pointed down (tube must be held vertically).

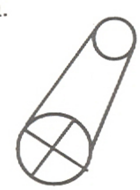
   c) For dead and down woody material, record "yes" or "no" for any root wads, logs, downed limbs, or bark seen through the tube (tube must be held vertically).

   d) For exotic or invasive species, record "yes" or "no" for any of these species (See Appendix H) seen through the tube (tube must be held vertically).

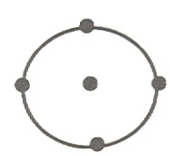
4) Calculate the percentage of sample points at each sample site which were answered by "yes". Use the aboveinformation and additional information provided in the forest stand summary sheet to tocalculate the forest structure value to be assigned to the site for each individual parameter.

5) Count number of shrubs found within a 1/100 acre plot. Shrubs can be most easily counted if the central stem can be identified.

a.



b.



(for more information see: James, F.C. and Shugart, H.H. 1970. A Quantitative Method of Habitat Description. Audubon Field Notes. 24: 727-36.)

Table D-3: Forest Structure Data Sheet

Property :
Stand #: **Plot #:**
Prepared by:
Date:

Forest Structure Variable	sample point 1	sample point 2	sample point 3	sample point 4	sample point 5	% yes
Canopy coverage						
herbaceous ground cover						
downed woody debris						
invasive plant cover						
number of shrub species (1/100 acre)						

Forest Structure Sampling Method:

1/10 acre plot,
5 sample points

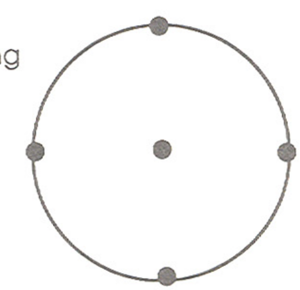


Figure D-3 Forest Structure Analysis

The following parameters will be measured and evaluated at each site according to Figure D-2. Each parameter at each sample site will be given a value of 3,2,1, or 0. Three represents the most valuable structure and , the least valuable. Upon completion of the sampling, the person preparing the FSD will caculate the forest structure value for each stand. This analysis along with the other forest stand data will be used to determine the retention potential of the stand.

To determine the total habitat value use the following scale:

Range of total habitat numbers from samples taken April - October:

15-21	Priority forest structure
7-14	Good forest structure
0-6	Poor forest structure

In the winter and late fall, from November - March, only numbers 1,3,4,5,7, can be measured. During that time, the range of total habitat numbers will be:

11-15	Priority forest structure
6-10	Good structure
0-5	Poor forest structure

1. Percent Canopy Closure of trees with a DBH greater than 7"

70% - 100 %	*3*
40% - 69%	*2*
10% - 39%	*1*
0% - 9%	*0*

2. Number of Understory Shrubs 1/100 acre

6 or more	*3*
4 - 5	*2*
2 - 4	*1*
0 - 1	*0*

3. Number of Dead Trees/tenth acre plot[1]

3 or more	*3*
2	*2*
1	*1*
0	*0*

4. Percent of Dead and Downed Woody Material Present

15% - 100%	*3*
5" - 14"	*2*
0 - 1	*1*
0	*0*

5. Size Class of Dominant Trees[1]

Greater than 20"	*3*
7" - 19.9"	*2*
3" - 6.9"	*1*
Less than 3"	*0*

6. Percent of Understory Herbaceous Coverage

75% - 100%	*3*
25% - 74%	*2*
5% - 24%	*1*
0% - 4%	*0*

7. Number of Tree Species with a DBH greater than 7"/plot[1]

6 or more	*3*
4 - 5	*2*
2 - 4	*1*
0 - 1	*0*

---

1 Data included in Forest Stand Summary Sheet (See Table D-4).

Table D-4 : Forest Stand Summary Sheet

Property Name:

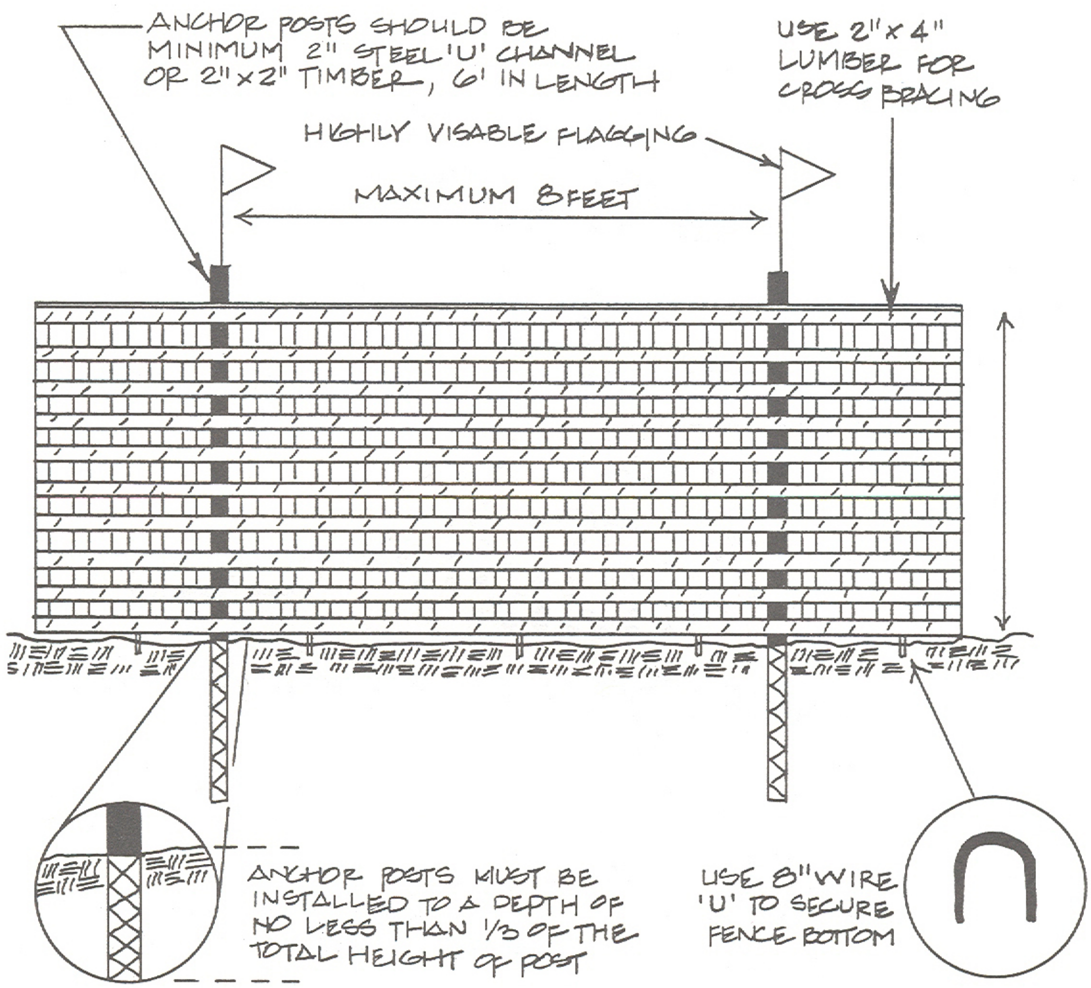
Prepared by:
Date:

Stand Variable	Stand # Acreage	Stand # Acreage
Forest Association (SAF cover type)		
Size class of dominant trees		
Number of Trees/acre		
Number of tree species/plot		
Basal area		
Number of dead trees/acre		
List of common understory species		
Number of shrubs 1/100 acre plot		
% Canopy coverage		
% Herbaceous cover		
% Downed woody material		
% Exotic or invasive species		
Forest Structure Value		
Comments		

APPENDIX B. TREE PROTECTION SPECIFICATIONS

This appendix contains specifications for tree protection techniques used during construction, including various types of fencing, berms, signs and hay bales. These specifications are taken directly from the Maryland Forest Conservation Manual. For further information on implementing these practices, see Greenfeld, et al (1991).

Figure J-4 **Blaze Orange Plastic Mesh**

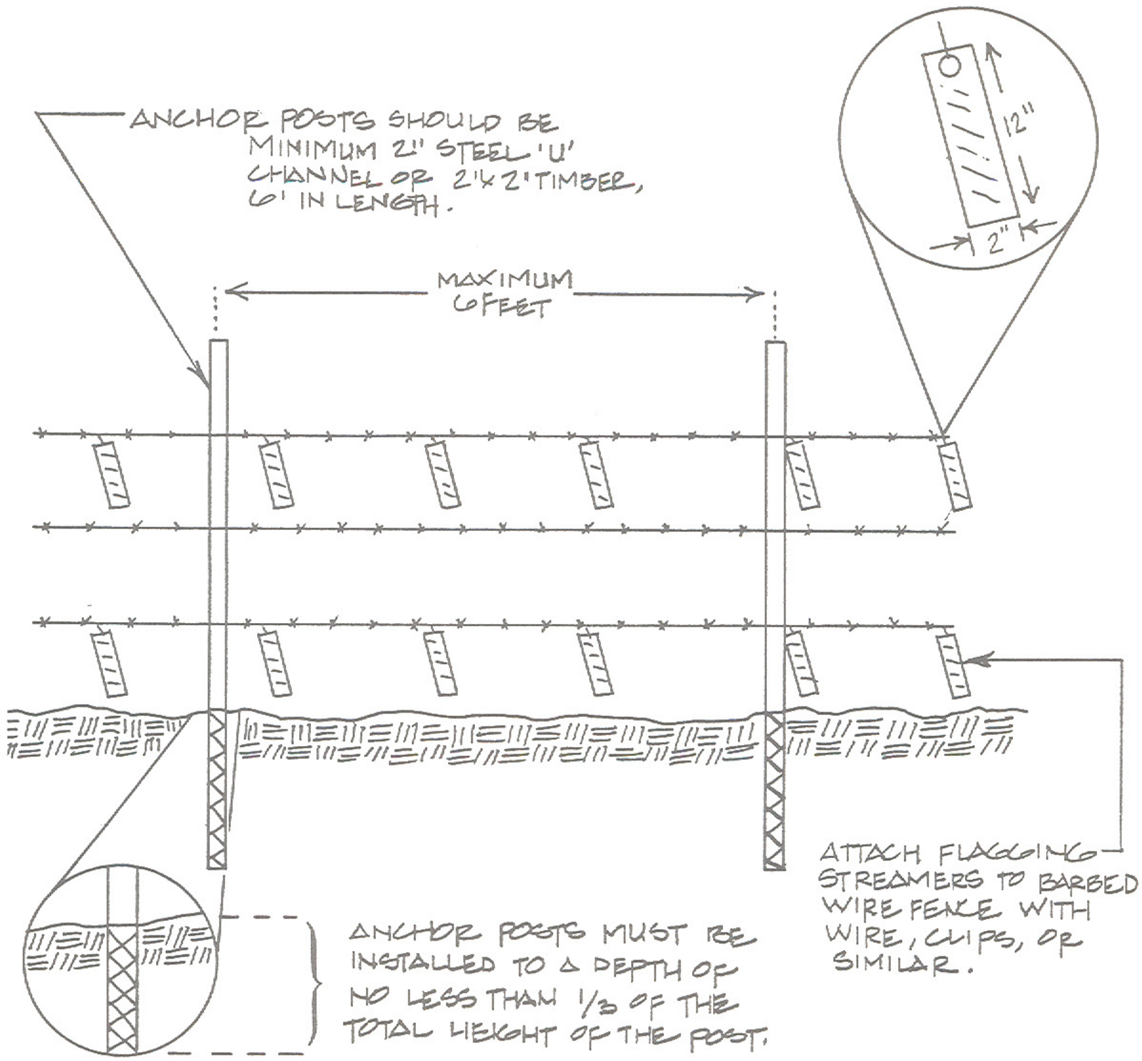


Notes

1. Forest protection device only.
2. Retention Area will be set as part of the review process.
3. Boundaries of Retention Area should be staked and flagged prior to installing device.
4. Root damage should be avoided.
5. Protective signage may also be used.
6. Device should be maintained throughout construction.

Source: Prince George's County, Maryland: Woodland Conservation Manual

Figure J-5 **Three Strand Barbed Wire**

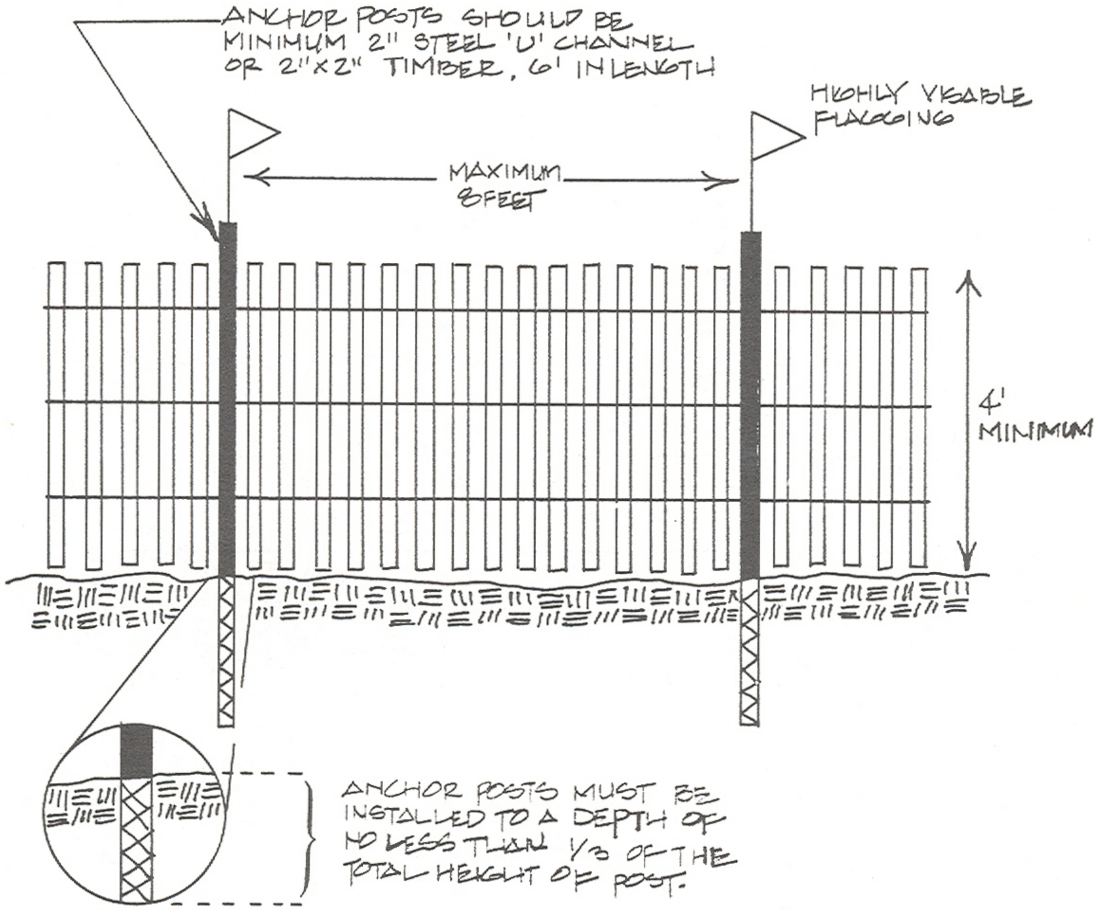


Notes

1. Forest protection device only
2. Retention Area will be set as part of the review process.
3. Boundaries of Retention Area should be staked and flagged prior to installing device.
4. Avoid root damage when placing anchor posts.
5. Barbed wire should be securely attached to posts.
6. Device should be properly maintained during construction.
7. Protective signage is also recommended.

Source: Prince George's County, Maryland: Woodland Conservation Manual

Figure J-6 **Snow Fence**



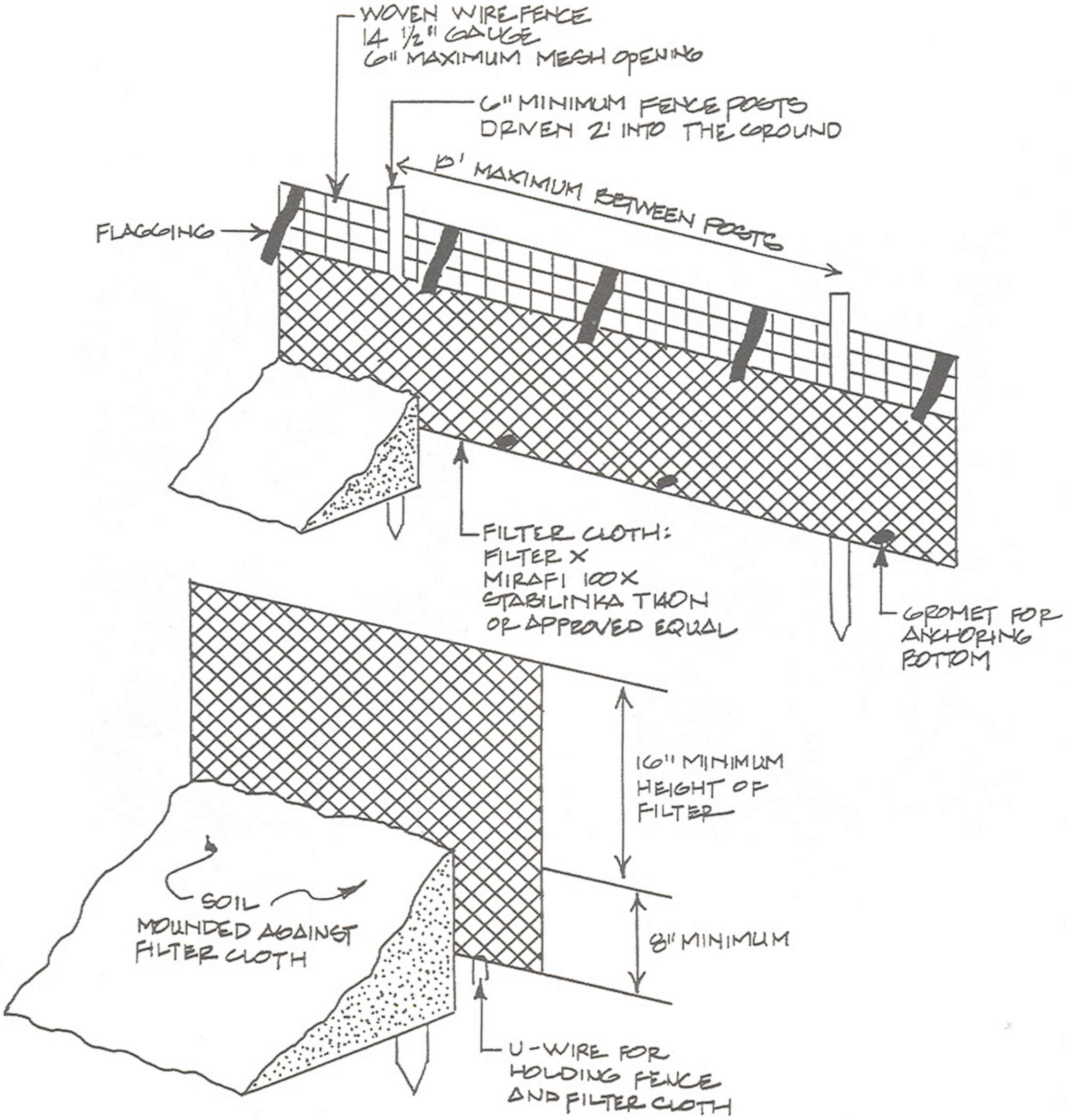
Notes:

1. Forest protection device only
2. Retention area will be set as part of the review process
3. Boundaries of Retention Area should be staked prior to installing protective device
4. Avoid root damage when placing anchor posts
5. Device should be properly maintained during construction
6. Protective signage is also recommended

Source: Prince George's County, Maryland: Woodland Conservation Manual

Figure J-7 **Signage**

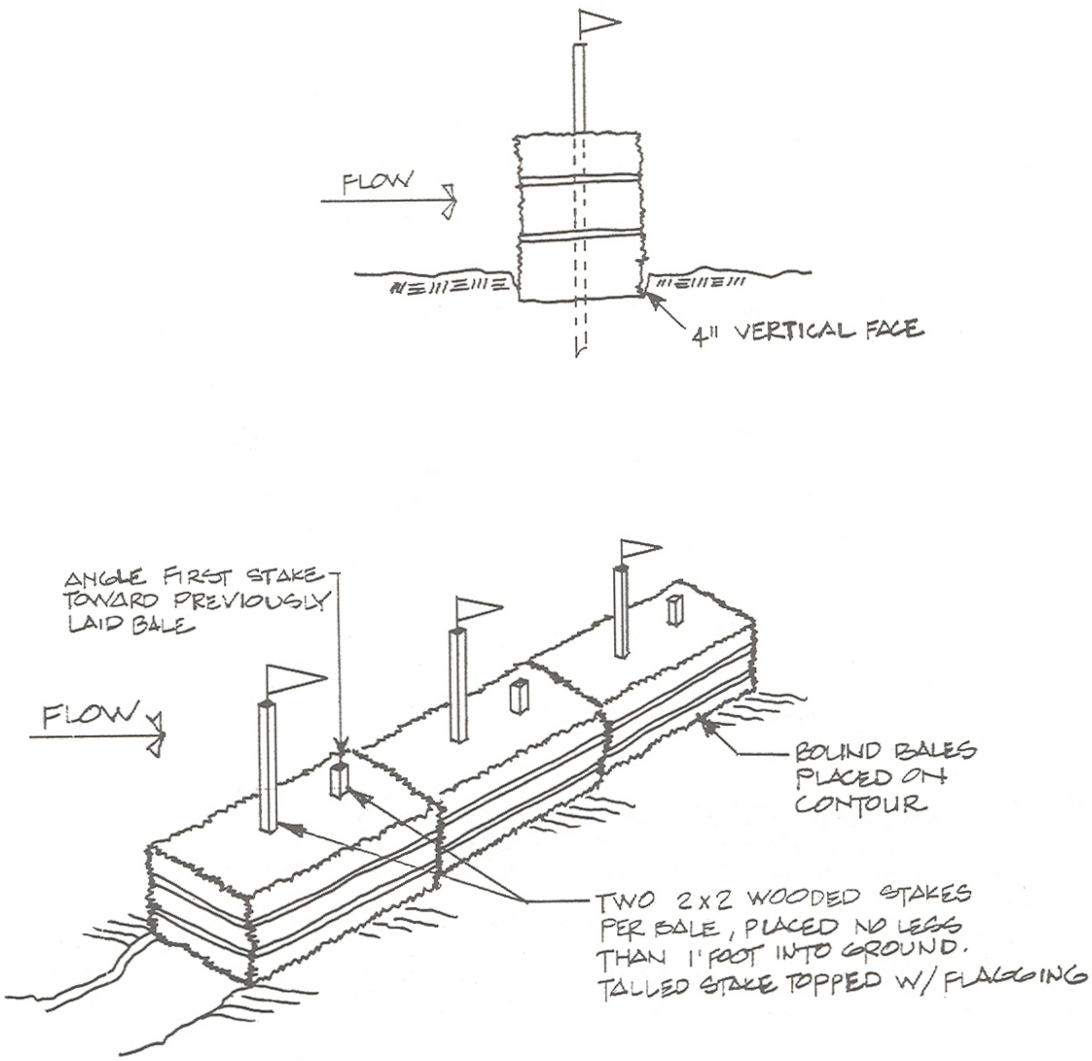
Figure J-8 **Filter Cloth on Wire Mesh**



Source: Prince George's County, Maryland: Woodland Conservation Manual

Notes:
1. Combination sediment control and protective device
2. Retention area will be set as part of the review process
3. Boundaries of Retention Area should be staked prior to installing protective device
4. Root damage should be avoided
5. Mound soil only within the limits of disturbance
6. Protective signage is also recommended
7. All standard maintenance for sediment control devices apply to these details

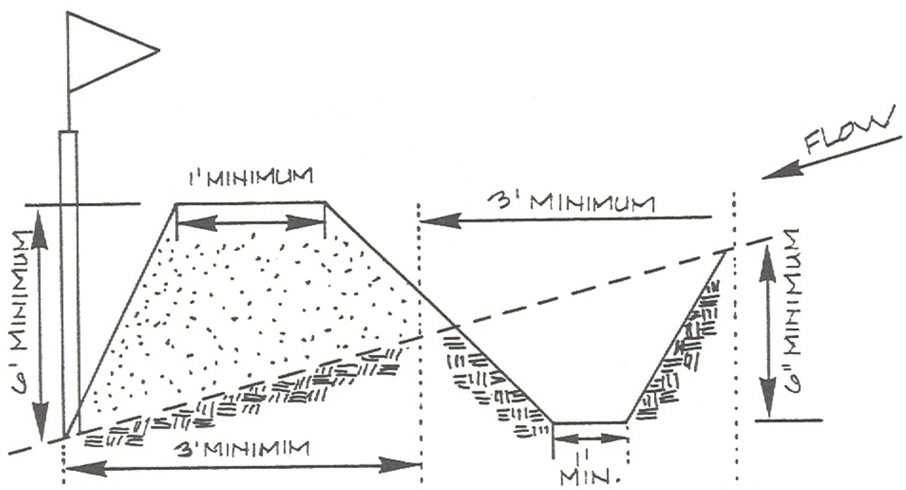
Figure J- 9 **Staked Straw Bale Dike**



Source: Prince George's County, Maryland: Woodland Conservation Manual

Notes:
1. Combination sediment control and protective device
2. Retention area will be set as part of the review process
3. Boundaries of Retention Area should be staked prior to installing protective device
4. Root damage should be avoided
5. This device should only be placed within the limit of disturbance
6. Protective signage is also recommended
7. All standard maintenance for sediment control devices apply to these details

Figure J-10 **Earthen Dike and Swale**



Notes:

1. Combination sediment control and protective device
2. Retention area will be set as part of the review process
3. Boundaries of Retention Area should be staked prior to installing protective device
4. Root damage should be avoided
5. The top or toe of slope should be within the limit of disturbance
6. Equipment is prohibited within critical root zone of retention area; place dike accordingly
7. All standard maintenance for earthen dikes and swales apply to these details
8. All standard reclamation practices for earthen dikes and swales shall apply to these details

Source: Prince George's County, Maryland: Woodland Conservation Manual

APPENDIX C. SITE ASSESSMENT FOR URBAN TREE PLANTING CHECKLIST

This appendix contains field sheets and instructions for conducting an assessment of potential urban planting sites. This assessment was developed by Cornell University's Urban Horticulture Institute and the field sheet and instructions are taken directly from the book *Recommended Urban Trees: Site Assessment and tree Selection for Stress Tolerance.* For additional information on site assessment, see Bassuk et al (2003) or the Cornell Urban Horticulture Institute website: www.hort.cornell.edu/uhi

SITE ASSESSMENT CHECKLIST

1. Site Location ______________________________

2. Site Description ______________________________

3. Climate

a. ***USDA Hardiness Zone***
__6b __5b __4b __3b
__6a __5a __4a __3a

b. ***Microclimate Factors***
__Re-reflected heat load
__Frost pocket
__Wind
Other ____________

c. ***Sunlight Levels***
__Full sun (6 hrs. or more)
__Partial sun or filtered light
__Shade

d. ***Irrigation Levels***
__No supplemental irrigation
__Automatic irrigation system
Irrigation amount and rate:
____

4. Soil Factors

a. ***Range of pH Levels*** _______
(Note actual readings on sketch)

b. ***Texture***
__Clayey
__Loamy
__Sandy

c. ***Compaction Levels***
__Severely compacted
__Moderately compacted
__Somewhat compacted
__Uncompacted

d. ***Drainage Characteristics***
__Presence of mottled soil
__Low-lying topography
Indicator plants suggest site drainage:
__wet __well-drained __dry
Percolation test results (in./hr.)
__poorly drained (< 4"/hr.)
__moderately drained (4"- 8"/hr.)
__excessively drained (> 8"/hr.)

e. Other Soil Considerations
__Indications of soil layer disturbance
__Evidence of recent construction
__Presence of construction debris
__Noxious weeds present:
____
____
____
____
__Evidence of excessive salt usage
__Erosion of soil evident
__Evidence of soil contamination
__Usage that compacts soil

f. ***Specific Soil Problems***
____
____
____
____
____
____
____

5. Structural Factors

a. ***Limitations to above-ground space***
___Overhead wires (height:_________)
Proximity to buildings/structures:
Other__________________________

b. ***Limitations to below-ground space***
__Utilities marked and noted on sketch
Approximate rooting volume for site
Length:__ Width: __ Depth: __

6. Visual Assessment of Existing Plants

a. *Species*	*b. Size*	*c. Growth Rate*	*d. Visual Assessment*

Sketch of Site

Note north arrow; circulation patterns; pH readings; location of overhead wires, underground utilities, buildings and pavement, as well as problem drainage areas.

COMPLETING THE SITE ASSESSMENT CHECKLIST

Suggested Tools and Materials

Cornell pH test kit and instructions
soil texture by feel instructions
wash bottle filled with water
at least 4 gallon jugs of water
paper towels
measuring tape
yardstick
shovel and trowel
plastic bags
wristwatch or timer
weed identification manual
ornamental plant identification manual
hand pruners
pencil/pen and extra paper

Optional tools: diameter tape, penetrometer, soil probe, vials containing alcohol for unknown insects, infrared thermometer

1. Site Location

Note the address of the site. You may also wish to note the nearest cross streets and/or page and grid of the maps your firm uses.

2. Site Description

A brief overview of the site including: general use or function, approximate size, accessibility, general topography (steep hill, gentle slope, etc.)

3. Climate

a. *USDA Hardiness Zone*

Check the USDA hardiness zone of the site. If planting in containers above ground you may want to regard the site as a zone colder than listed, as trees in containers are more susceptible to cold winter temperatures than trees in the ground.

b. *Microclimate Factors*

Re-reflected heat load: Determine if the site, or some portion of it, has heat pockets due to reflected and reradiated heat loads from pavement, automobiles, buildings or other surfaces. This can cause a tree to heat up and lose water from its leaves at a faster than normal rate. These pockets are often south facing and have a tremendous amount of heat load. On sunny days, these areas will be noticeably warmer than nearby spots. Drought-resistant trees should be chosen in these situations.

Frost pocket: Frost pockets are often found in low areas at the bottom of a slope or bowl. Cooler air, being heavier, collects in these areas, lowering air temperatures.

Wind: Excessively windy sites will often place stress on trees, particularly those with large leaves which may result in leaf tatter. Also, trees in these sites may need supplemental watering to prevent them from drying out as quickly. Signs of excessive wind are trees leaning or growing in the same direction. Plants will have stunted growth on the side that faces the full force of the prevailing wind. Wind tunnels are common in urban areas where wind is funneled between tall buildings.

Other: Are there other factors that might affect the climate or precipitation levels? For example, are there wide rain shadows formed by the overhang of a building? Is the site located near a large body of water that may moderate the climate?

c. *Sunlight Levels*

Shady sites determined by the sun and shade patterns around buildings may limit the choice of trees. Consider that a site has full sun if it receives more than 6 hours of direct sunlight. Partial sun has direct sun (often morning sun) for less than 6 hours, or filtered light (as would be common under a tree with fine textured eaves) for most of the day. An area is consider shady if it receives little or no direct sunlight, or if it receives less than 6 hours of filtered light.

d. ***Irrigation Levels***

Note the presence or absence of an automatic irrigation system. If possible record the method of delivery (overhead, drip, mini-sprinkler), the weekly amount of water applied and the rate at which it is applied. You may wish to test the system by setting out collection containers in different on the site and running the system for a specified amount of time to test the delivery rate. Comparing the actual amount delivered with the manufacturer's specifications for the system will indicate its efficiency.

4. Soil Factors

a. ***Range of pH Levels***

Check the pH for several areas on the site. Pay particular attention to the pH near sidewalks and parking areas, concrete or masonry buildings or foundations. These limestone-containing materials in the street environment result in the high ph levels (from neutral to alkaline) of most urban soils. Note the range of levels on the front side of the checklist. Note the sample locations and exact readings on the sketch on the back of the checklist.

b. ***Texture***

In the field, test the soil texture using the soil texture-by-feel technique, and record the results on the checklist. If you must know the exact soil texture, record the general soil type on the checklist and collect several samples to be analyzed by a soils lab. A sandy soil will suffer less from the effects of compaction but may be less able to supply water to trees. Conversely, compaction may render a heavy clay soil too wet, making oxygen less available.

c. ***Compaction Levels***

There are several ways to test for soil compaction. A simple one is to use a penetrometer. Record the average depth of penetration at which the probe measures 300 psi. Alternately, you may take several soil cores using a soil probe and analyze them for soil density. Perhaps the simplest test is to dig a small pit and gauge the difficulty of hand digging. Repeat the 'shovel test' in several spots.

d. ***Drainage Characteristics***

Determining the drainage characteristics of your site is a multi-faceted task.
Presence of mottled soil: The strongest indication of poor drainage is mottled soil. Dig a soil pit at least 12" to 15" deep and remove several clods for examination. Clods that have grey mottling and/or have a foul odor indicate poor drainage.
Low-lying topography: Study the topography for low-lying areas that collect surface runoff and that may be poorly drained.
Indicator plants: Plants that indicate poorly drained (wet) sites include Willow, Pin Oak, Swamp White Oak, and Tupelo. Plants that indicate moist soils are sycamore and tulip trees. Plants that indicate well-drained sites are sugar maple, red oaks and hickories.
Percolation test: To perform a percolation test, dig a pit approximately one foot deep. Fill the pit with water and allow this water to drain completely. Once the water has completely drained, refill the pit with water, measure the depth of water in the pit and note the time. After 15 minutes, note the depth of water and calculate the rate of drainage in inches per hour. (The initial filling and draining of the pit is to saturate the soil to test more closely for gravitational water movement.) Classify the soil into one of the three drainage classes: poorly drained (< 4"/hr); moderately drained (4"-8"/hr); or excessively drained (> 8"/hr).

e. ***Other Soil Considerations***

Indications of soil layer disturbance: Look for areas that show evidence of regarding cuts or fills. Clues include mature trees that do not show a trunk flare (due to soil piled against the trunks), or have retaining walls near their bases. You may wish to dig a pit approximately two feet deep in order to examine the soil horizons, especially if the site has recently had construction activity. Soil layers that are noticeably lighter in color than lower layers indicate that subsoil has been spread on top of the original grade. Conversely, the absence of a rich brown, organic layer at the top may indicate that the topsoil has been removed.

Evidence of recent construction: Clues include newly-pave surfaces, turf that is noticeably thinner than in surrounding areas, new retaining walls, soil 'humps' or subsidence, and the like. Also consider the route or routes taken by heavy equipment into the site and where materials were stored during construction.

Presence of construction debris: Construction debris is likely on almost all construction sites, particularly if tipping fees for debris are high in your area, and if construction involved the renovation or removal of a building or pavement.

Noxious weeds present: Use a guide to identify weeds. Pay particular attention to perennial noxious weeds that must be eradicated before landscape installation. Perennial weeds that are commonly found in urban landscapes include: bindweed, poison ivy, mugwort, wild violet, nutsedge, quackgrass, and healall.

***Evidence of excessive salt usage/salt injury*:** Look (particularly near walks and parking areas) for white powder that has precipitated out on the soil surface. Prostrate knotweed is a weed that indicates salty compacted soil. Brown needle tips, marginal leaf scorch, or witches' broom on ornamentals indicate salt injury. Carefully examine areas where salt-laden snow has been dumped. These areas are likely to have high soil salt concentrations.

Erosion of soil evident: Determine the extent and severity of soil erosion. Note the presence and size of eroded gullies, rills, or soil slumps. Factors that affect soil erosion include: rainfall intensity, quantity, and runoff; slope length and gradient; amount of stabilizing plant material or other erosion control practices; the infiltration rate and the structural stability of the soil.

Evidence of soil contamination: Look for signs of dumping by restaurants or open-air food stalls of wash water, old dumping areas, construction dumping areas, oil and gas dumping, and the like.

Usage that compacts soil: Is the area used for open-air markets or parties? Are there pathways that pedestrians have created? Is the area sometimes used for parking? Are there other social activities that are planned for the site that tend to compact the soil?

f. ***Specific Soil Problems***

Use this space to record specific soil problems that occur on the site.
Problems might include an inability to surface drain a site, possible soil chemical contaminants, and the like.

5. Structural Factors

a. ***Limitations to above-ground space***

Overhead wire height: Describe the location and estimate the height of over head utility wires.

Proximity to buildings and structures: Note the location of buildings and structures on the back of the checklist. Check the box on the front side of the checklist if you anticipate buildings or structures having an impact on the canopy space of landscape plantings.

Other: Are there any other limitations to above-ground space? Examples include: building or planting setbacks, emergency access lanes that must be kept clear, heat vents, and signs that must be readable from the road.

b. ***Limitations to below-ground space***

Utilities: Mark utilities on the sketch. Identify individual utilities if possible. Know that you must hand dig within two feet on either side of the marked line.

Estimate rooting volume: In order to estimate the available rooting volume of a planting site, measure the length and width of available soil, and multiply area by the estimated depth of rooting. Remember that compacted soil will have a very shallow rooting depth.

6. Visual Assessment of Existing Plants

a. *Species*

Identify the species of plant. The more specific identification is, the better. You may wish to collect leaf and/or bud samples to bring back to the office for identification of obscure plants or plants not in leaf.

b. *Size*

Approximate the height and spread of the plant material using the following field method: Place a yardstick (or other object of known height) against the trunk. Step back so that the whole tree is in your sight. While holding a pencil or pen at arm's length, line up the top of the yardstick with the tip of the pencil. Using your thumbnail, mark the base of the ruler on the pencil. Sighting up the tree, determine how many 'rulers' fit into the tree. Multiply this number by the length of the yardstick for a height approximation. Use the same method to estimate the canopy spread. You may also wish to note the diameter of the trunk at breast height (4.5' above ground level).

c. *Growth rate*

Quantify this year's annual shoot extension by measuring the twig length between growth tip (terminal bud) and the bud scale scar. Past years' growth is the length between bud scales. Measure several branches growing in the sun in the upper 2/3 of the canopy. Record the average growth rate. Less than 2" of growth is considered poor, 2" to 6" is moderate growth, and greater than 6" per year is vigorous growth.

d. *Visual Assessment*

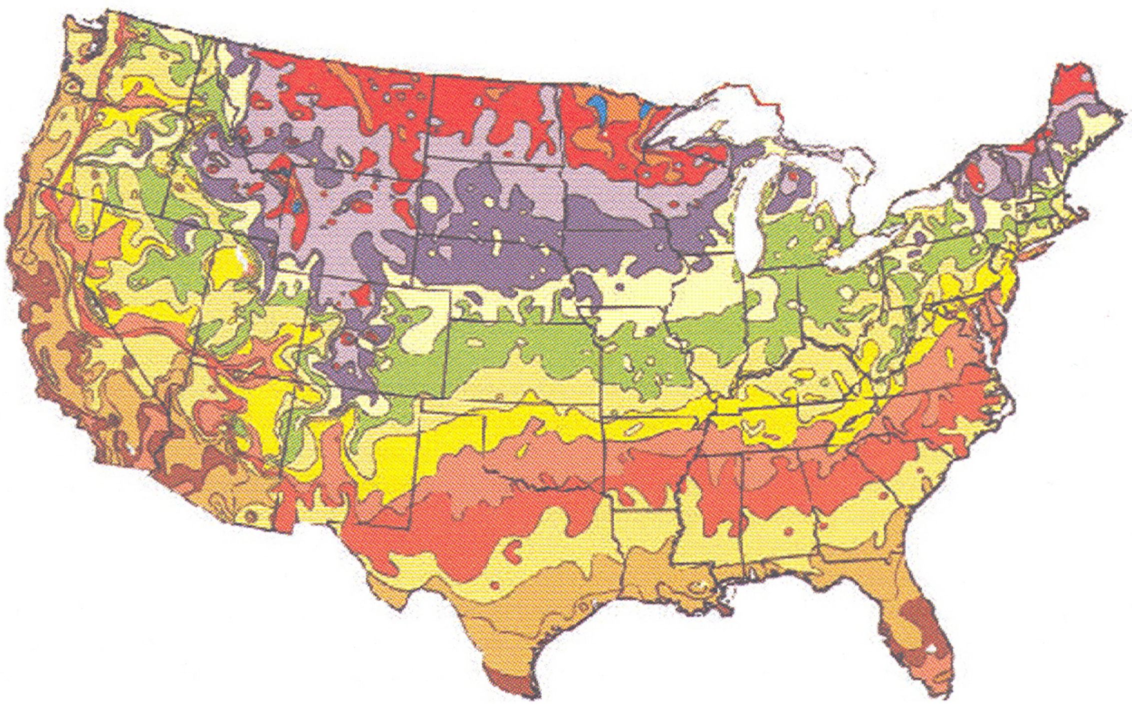
In general: Note aesthetic quality and general health of each plant. Indicate mechanical injury to plant parts. Also note the presence of insects or disease. Keep in mind that diseases and insects often attack stressed trees and may not be the primary cause of health problems.

Trunk assessment: Look for evidence of mower or string trimmer damage at the base of the trunk. Also look for excessive suckering or bark splitting. Note any trees that do not exhibit a trunk flare (indicative of recent regrading activity or that it was planted too deep).

Roots: Note excessive surface rooting and girdling roots. These may signify poor drainage, too-deep planting, and/or compacted soils. Test the stability of newly planted trees by gently rocking them. If there is excessive movement, the trees may have root problems, or the roots were never able to establish after transplanting.

Leaves and branches: Stressed trees often exhibit small, off-color leaves that drop early in the fall. Also note trees whose leaves show marginal leaf scorch and whose branches have tip die-back. If there is significant die-back, is it all on one side of the canopy or is it on both sides? Do all of one species on the site exhibit the same symptoms? Note the presence of witches' broom, watersprouts, or other abnormalities.

USDA PLANT HARDINESS ZONE MAP



AVERAGE ANNUAL MINIMUM TEMPERATURE

Temperature °C	zone	Temperature °F
-456 & below	1	below -50
-428 to 455	2a	-45 to -50
-40.1 to 42.7	2b	-40 to -45
-373 to -400	3a	-35 to -40
-345 to -372	3b	-30 to -35
-317 to -344	4a	-25 to -30
-289 to -316	4b	-20 to -25
-262 to -288	5a	-15 to -20
-234 to -26.1	5b	-10 to -15
-206 to -233	6a	-5 to -10
-178 to -205	6b	0 to -5
-15.1 to -17.7	7a	5 to 0
-123 to -150	7b	10 to 5
-95 to -122	8a	15 to 10
-6.7 to -9.4	8b	20 to 15
-39 to -66	9a	25 to 20
-12 to -38	9b	30 to 25
16 to -1.1	10a	35 to 30
44 to 1.7	10b	40 to 35
45 & above	11	40 & above