Understanding the Science Behind Riparian Forest Buffers:

Planning, Establishment, and Maintenance

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The riparian area is that area of land located immediately adjacent to streams, lakes, or other surface waters. Some would describe it as the floodplain. The boundary of the riparian area and the adjoining uplands is gradual and not always well defined. However, riparian areas differ from the uplands because of their high levels of soil moisture, frequent flooding, and unique assemblage of plant and animal communities. Through the interaction of their soils, hydrology, and biotic communities, riparian forests maintain many important physical, biological, and ecological functions and important social benefits.

Understanding the Science Behind Riparian Forest Buffers:

Planning, Establishment, and Maintenance

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Riparian forest buffers can enhance water quality, provide wildlife habitat, and benefit individuals and communities. However, to achieve these benefits, careful planning is essential. Prior to establishment, it is critical to clearly define what the buffer is intended to accomplish. Observations on the stream's condition and on the adjoining watershed will help determine how wide the buffer should be, what types of vegetation should be restored, and how the site should be prepared before planting. Once a buffer is established, a long-term maintenance plan is also required to assure the project's success.

"River restoration is a multidisciplinary art that involves some knowledge and experience in hydrology, geology, soil science, aquatic habitats, civil engineering, forestry, and horticulture." Deborah G. Mills, Virginia Department of Conservation and Recreation

Objectives

The first step in designing the buffer is to clearly define what the buffer is expected to accomplish (Figure 1). Consider these questions: Are there water quality problems that need to be addressed? Is wildlife a primary objective, and if so, what are the species of interest? Are aesthetic and recreational benefits important? Are there any financial, personal, or time constraints that will interfere with buffer establishment or future maintenance? How will placement of the buffer affect the management of the land? Remember, the restoration of riparian forest buffers is a long-term process requiring the ongoing commitment and involvement of the landowner.

Site Assessment

Next, evaluate the area and determine if site conditions can reasonably be expected to produce the desired benefits. The evaluation should take a look at stream conditions upstream and down, as well as in the immediate area (Table 1).

Watershed

To understand the forces affecting a particular stream segment, it is important to look at the entire watershed (Figure 2). A stream is influenced by many factors, including the area's geology, hydrology, soils, and vegetation. However, one of the most important influences on the stream is adjoining

Fig 1. The first step in designing the buffer is to clearly define objectives. (Photo by Ken Hammond, courtesy USDA)

Fig 2. To understand the forces affecting a stream, it is important to consider land uses throughout the watershed.

Table 1. Site Assessment Checklist

Watershed Considerations	Site Considerations - Riparian Area	Site Considerations - Stream
Hydrology	Hydrology	Stream order and size
Geology	Width of 50 and 100 year floodplain	Flood frequency
Topography	Soil characteristics	Water velocity
Watershed size	Slope	Channel shape, width, depth, slope
Intensity and type of land use	Riparian vegetation	Streambank stability
Sediment and nutrient loadings	Wildlife resources	Presence of pools, riffles, runs
	Cultural resources	Channel substrate
	Human disturbance	Water quality
		Aquatic community

land uses. For example, streams which flow through urban areas are subject to higher pollution loads and warmer temperatures. In rural areas, agricultural activities can contribute sediment and nutrients and damage streambanks from livestock grazing. Other activities, such as industry, mining, dams, and wastewater treatment facilities can also influence the character of streams, including water chemistry, stream temperatures, and flow rates. When stream systems are severely degraded or unstable as a result of watershed uses, riparian restoration is likely to be unsuccessful until the source of the problem is addressed.

Aerial photographs, soil survey maps, topographic maps, geological maps, and land use maps provide useful information on a watershed level (Figure 3). Attempt to identify:

1. Where is the stream located in the watershed? Is it a headwater stream, a mid-order stream, or a major stream artery?

2. How is the riparian area linked hydrologically with the uplands and with the stream?

3. What is the most important water quality problem in the watershed? Where and when does the maximum discharge of pollutants occur?

4. What fish and wildlife species are found in the area and how might they be influenced by the buffer?

5. What will be the impact of placing a buffer at this particular location? Will watershed land uses override the ability of the buffer to produce the expected benefits? (Schnabel and others 1994, King and others 1997).

Fig 3. Maps and aerial photographs can provide useful information about the surrounding watershed. (Photo by Ken Hammond, courtesy USDA)

Riparian Area

The condition of the riparian area, including hydrology, soils, and vegetation, should be the next focus of the evaluation (Figure 4).

Fig 4. Riparian area hydrology, soils, and vegetation should be evaluated. (Photo by Bob Nichols, courtesy USDA)

Hydrology

Riparian area hydrology can be difficult to evaluate; however, the lay of the land, the steepness of slopes, and observations of soil conditions during the wet season can provide valuable clues. If soils are saturated, this is a good indicator that groundwater flows close to the surface. Well-drained soils indicate deeper groundwater flows. The absence or presence of wetlands and observations of sediment deposits and erosion patterns also provide useful information (Palone and Todd 1997). The width of the floodplain and flood frequency, duration, and season are other important hydrological features.

Soils

Soil survey maps describe and characterize the types of soils found in the riparian area. However, riparian area soils can be highly variable, even within short distances (Myers 1989). Therefore, soils should be sampled at intervals to determine soil type, texture, pH, presence of mottling, a clay layer, and other attributes.

Vegetation

Existing riparian vegetation can be a good indicator of which species will grow well on the site. Vegetation can also provide valuable clues to the area's soils and hydrology. Species, age, and density of the vegetation as well as presence of exotic invasive species should be noted. The presence of wildlife and wildlife habitat, cultural resources, and human disturbance should also be recorded.

Stream

Fig 5. Evaluate the condition of the stream and its channel.

Before the riparian forest is re-established, it is important to evaluate the condition of the stream and its channel (Figure 5). Although it is natural for streams to shift their courses through time, land activities can dramatically accelerate the process. When this occurs, it is necessary to stabilize the channel before attempting to restore riparian vegetation. If the erosion is especially severe, the source of the problem must first be addressed or the restoration is likely to be unsuccessful.

To determine whether the stream is stable or undergoing rapid change, some basic observations are needed. First, observe the shape of the stream channel. Straight streams are rare in nature (except on steep slopes), and are usually an indication that the stream has been channelized. Through time, channelized streams will move about as they try to regain their natural course. Stable streams, on the other hand, are sinuous, or "S"-shaped. Channel width, depth, and slope should also be noted. In areas where the land has been cleared or paved, streams often become entrenched with steep vertical banks, due to the increased volume and velocity of storm runoff. Streams with high sediment loads from eroding land will develop sediment deposits within the streambed and become more shallow and wider. Besides the stream channel, observe the streambank. Streambanks that are well vegetated and show little erosion usually are stable. Steep banks, frequent treefall, poor bank vegetation, and widening of the stream channel are indicators of unstable conditions.

Next, look within the stream. Healthy streams usually have a combination of pools (deep sections outside of bends and below large rocks and woody debris), riffles (shallow areas where water bubbles over rocks), and runs (straight sections). Usually, there are two to three pools and two to three riffles between each bend in the stream, with each pool and riffle spaced at distances 2.5 times the stream width. Streams also have a characteristic "bedload" (a combination of sand, silt, gravel, and large rocks), which is related to the geology of the area and waterflow. In eroding streams, sandbars and sediment deposits are often found. The presence of overhanging trees, large woody debris within the stream, and aquatic vegetation are important features of healthy streams. Finally, make observations on water quality (color, odor, presence of algae, etc.) and the composition of invertebrate and fish communities (Myers 1989, Hoffman and others 1998).

Design

Three-Zone Riparian Forest Buffer System

In 1991, the U.S. Department of Agriculture developed guidelines for restoring riparian forest buffers (Welsch 1991). These guidelines are based on a "three-zone approach" to restoring forest buffers, with

Rosgen Stream Classification System

A commonly used system for evaluating stream stability was developed by David Rosgen (1994). The Rosgen classification system is based on the principal that the shape of the stream channel is directly influenced by stream velocity and discharge, sediment load and size, channel width, depth and slope, and type of bed material. A change in one of these variables results in a series of adjustments in all of the others, and ultimately a change in the pattern of the stream. For example, in response to increased bank erosion, the stream may become wider and more shallow, become less sinuous, increase the slope of the river bed downstream, or form sandbars. If these factors are measured and understood, they can be used to predict the stream's response to changes in the adjoining watershed, the stream's potential for recovery, and to select the best design for long-term stability.

For more information see:

1) Rosgen, D.L. 1994. A classification of natural rivers. Catena. Volume 22 pages 169-199.

2) Austin, S.H. 1999. Riparian forest handbook 1 - Appreciating and evaluating stream side forests. Virginia Department of Forestry. Charlottesville, VA. 48 pages.

each zone providing a specific function (Figure 6). Zone 1 is nearest to the stream and is an area of undisturbed forest that stabilizes streambanks, provides shade, moderates stream temperatures, and provides large woody debris to the stream. Zone 2 is an area of managed forest adjacent to Zone 1. The purpose of Zone 2 is to improve water quality through vegetative uptake (of nutrients and toxins) and biogeochemical processes in the soil. Native deciduous trees are recommended for planting in Zones 1 and 2 to maximize habitat value for fish and wildlife and water quality benefits. As the trees in Zone 2 mature, selective timber harvesting and timber stand improvements are necessary to promote vigorous growth of the remaining trees. Zone 3 is an area of dense grass that lies between the forest buffer and adjoining land uses. The purpose of Zone 3 is to slow and spread concentrated flows of water coming from the land, which will promote the release of suspended sediments and the infiltration of surface runoff into the ground. Native warm-season grasses are recommended for planting in Zone 3 because of their tall, stiff stems and their deep root systems (Schultz and others 1995).

Width

One of the first questions most landowners ask is: How wide does the riparian buffer need to be? Unfortunately, there is no one single "ideal" buffer width. The proper buffer width depends on site characteristics and the benefits expected from the buffer. In the Chesapeake Bay region, a buffer of 35 feet on each side of the stream is generally suggested to benefit the aquatic community, with the buffer expanding to 75 to 100 feet per side to produce water quality and wildlife benefits (Palone and Todd 1997). Other researchers have suggested different "rules of thumb" for determining the proper buffer width. Verry (1996), a hydrologist with the U.S. Forest Service in Minnesota, suggests that a proper width for riparian management is "the active 50-year floodplain plus the terrace slopes," or approximately 10 times the stream "bankfull" width plus 50 feet on either side (Verry 1996). In the Pacific Northwest, a team of scientists known as the Federal Ecosystem Management Assessment Team (FEMAT) recommends buffer widths (per side) equal to the height of a "site-potential tree," or the average maximum possible tree height for that site (the average "site-potential tree" in the eastern U.S. is 110 ft.) (O'Laughlin and Belt 1995). They suggest that many buffer functions (for example, providing shade, leaf litter, large woody debris, and stabilizing streambanks) are met with a buffer width of one site-potential tree height. However, others suggest that wildlife and water quality benefits require a wider buffer.

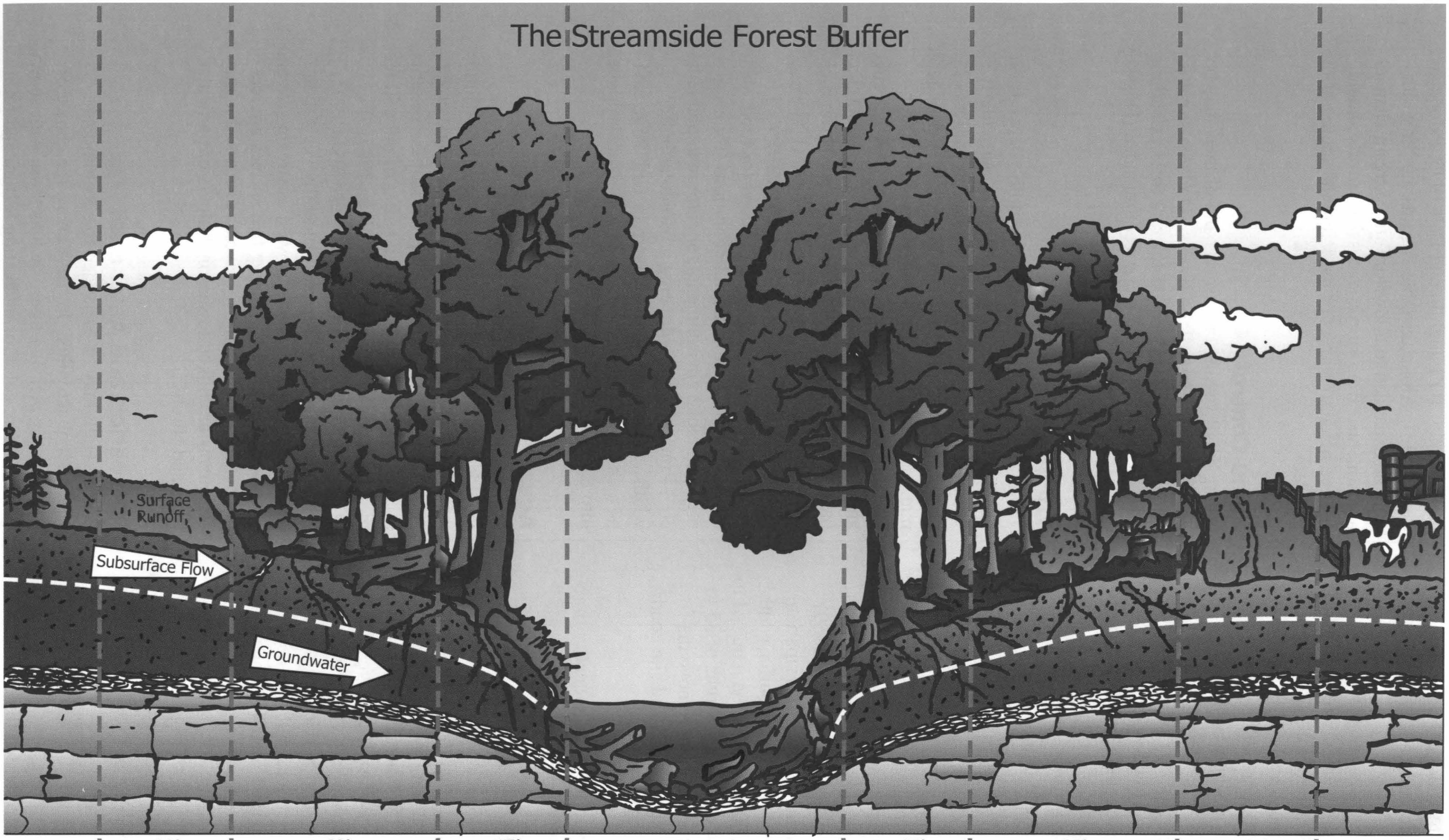
Stream size and stream order can also influence the size of the buffer needed. Headwater streams, for example, may not require the same degree of buffering as larger streams to provide the same benefit (Palone and Todd 1997). Buffer widths should also account for the goals of the landowner and the desired functions (Table 2).

Water Quality

Designing riparian forest buffers to improve water quality is complicated by the need to control three different types of pollutants at the same time: sediment-adsorbed pollutants in surface runoff, dissolved pollutants in surface runoff, and dissolved pollutants

Table 2. Range of minimum widths for meeting buffer objectives.

Water quality Objective	Buffer width (ft)	Considerations
Nutrient removal	15-200	Depends on hydrology, soils, loadings.
Sediment control	30-300	Depends on slope, soil type, sediment loadings.
Streambank stabilization	25-55	Choose deep-rooted species that readily resprout.
Flood control	25-200	Depends on stream order and flood patterns. Select sturdy flood-tolerant species.
Wildlife habitat	25-300	Depends on species of concern. Select native plant species for revegetation, particularly those that provide high value for food and shelter.
Aquatic habitat	60-110	Select native trees and shrubs for seasonal inputs of leaf litter and inputs of large woody debris.
Water temperature moderation	50-110	Depends on stream size and aspect, and the height, density, and crown size of the vegetation



CROPLAND	20′ ZONE 3 RUNOFF CONTROL	60′ ZONE 2 MANAGED FOREST	15′ ZONE 1 UNDISTURBED FOREST	STREAMBOTTOM	15′ ZONE 1 UNDISTURBED FOREST	20′ ZONE 2 MANAGED FOREST	60′ ZONE 3 RUNOFF CONTROL	PASTURE
Sediment, fertilizer and pesticides are carefully managed.	Concentrated flows are converted to dispersed flows by water bars or spreaders, facilitating ground contact and infiltration.	Filtration, deposition, plant uptake, anaerobic denitrification and other natural processes remove sediment and nutrients from runoff and subsurface flows.	Maturing trees provide detritus to the stream and help maintain lower water temperature vital to fish habitat.	Debris dams hold detritus for processing by aquatic fauna and provide cover and cooling shade for fish and other stream dwellers.	Tree removal is generally not permitted in this zone.	Periodic harvesting is necessary in Zone 2 to remove nutrients sequestered in tree stems and branches and to maintain nutrient uptake through vigorous tree growth.	Controlled grazing or haying can be permitted in Zone 3 under certain conditions.	Watering facilities and livestock are kept out of the Riparian Zone insofar as practicable.

Fig 6. The three-zone riparian buffer system. (Figure courtesy D. J. Welsch, USDA Forest Service)

in groundwater (Palone and Todd 1997). The design must also take into account the area's hydrology, soils, and pollutant loads.

Buffers of 50 to 100 feet are generally recommended to trap sediment, although wider buffers are required where there are high sediment loads or steep slopes (as a rule of thumb, the buffer should expand about 5 feet for every 1% increase in slope) (Palone and Todd 1997). On flat sandy soils where sediment loads are low, narrower buffers may be as effective (Magette and others 1989). However, only very wide buffers will be effective in trapping small clay particles. For example, researchers in Arizona found that grass buffers trap most sand from shallow surface runoff within about 10 feet and trap most silt within 50 feet, but found that 300 to 400 feet of buffer was required to trap small clay particles (Wilson 1967). Similar observations were made in a riparian forest in North Carolina (Cooper and others 1987).

The ability of the buffer to remove dissolved pollutants like nitrate is variable and tied to the site's soils and hydrology. For example, when Phillips (1989) examined the buffering capacity of various riparian soils in North Carolina, he found that a buffer width of anywhere from 16 to 300 feet would be required to remove nitrates from field drainage. Widths of 35 to 125 feet are usually recommended to remove dissolved pollutants, depending on loads and site conditions (Palone and Todd 1997).

To restore riparian buffers to meet water quality functions, David Welsch of the U.S. Forest Service Northeast Area recommends a width of 75 feet per side based on the "three-zone system" (Zone 1 - 15 feet, Zone 2 - 60 feet, and Zone 3 - 20 feet) (Welsch 1991). However, he suggests that the buffer should be expanded where frequent flooding occurs (soils of Hydrologic Groups C and D), where certain soil types are present (Soil Capability Class IIIe/s, IVe/s, Vie/s, VIIe/s or VIII) and on steep slopes. The USDA Natural Resources Conservation Service recommends a minimum buffer width of at least 30% of the geomorphic floodplain, or at least 15 feet for Zone 1 and 20 feet for Zone 2 on all streams.

Dillaha and Hayes (1991) of Virginia Tech recommend delineating "subwatersheds" (drainage areas) within the area to be protected and designing buffers to fit each.

Bank Stabilization

Where bank erosion is moderate, widths of 25 feet to 55 feet are recommended to stabilize and maintain streambanks (O'Laughlin and Belt 1995, Palone and Todd 1997). Along unstable streams, buffer width may be expanded to allow for future stream channel adjustments. If erosion is excessive, efforts should first be made to correct or moderate the source of the problem.

Flood Control

Along small streams, a narrow band of trees may be enough to moderate flood waters. On large streams, wide buffers of sturdy flood-tolerant trees extending throughout the floodplain are recommended (Dosskey and others 1997).

Wildlife

The choice of a buffer width for wildlife depends on the species of interest. Some animals, particularly "edge species," may require only narrow buffers (25 feet or less) for their needs, while others such as large mammals and certain birds may require a buffer of 100 to 300 feet (Croonquist and Brooks 1991, Keller and others 1993). Forested areas as wide as 600 feet have been recommended where there are heron rookeries, bald eagles, or cavity-nesting birds (USDA Natural Resources Conservation Service 1996c). When managing for wildlife, the need for food, shelter and certain environmental conditions (for example, cool moist environments for certain amphibians) are as important as a creating a particular buffer width. Features such as snags, trees with large cavities, and mast-producing trees should be incorporated into the buffer plan.

Aquatics

Important considerations for aquatic communities include inputs of food and structural elements (limbs, logs, overhanging roots) to provide shade and cover. A buffer of 60 to 110 feet will provide these benefits, although along small streams, a buffer of only 50 feet may be adequate (Dosskey and others 1997, O'Laughlin and Belt 1995, Palone and Todd 1997). Stream protection will be influenced by vegetation height, density, crown size, as well as stream size and aspect (Quigley 1981). Native tree species are recommended, because the life cycles of many aquatic organisms are linked to seasonal inputs of particular trees and shrubs.

Recreation and Aesthetics

Buffer width may be expanded to accommodate recreational activities. In these areas, the choice of aesthetically pleasing trees, such as those with showy flowers, fruit, color, or interesting texture and form may be appropriate.

Marketable Products
Landowners who wish to harvest a marketable product from the buffer must choose the appropriate species for planting. Depending on the product, the buffer width may need to be increased for the operation to be productive and economically viable.

Restoration
Restoration of the riparian forest buffer includes stabilizing the stream channel, preparing the site, planting the vegetation, and regular maintenance.

Streambank Stabilization
Streambank stabilization may include a combination of vegetative and structural engineering techniques (USDA Natural Resources Conservation Service 1992). Vegetative techniques such as live stakes, tree revetments, live fascines, and brush mattresses are often the best choice, due to their low expense, their more natural appearance, and the additional benefits provided to fish and wildlife (Firehock and Doherty 1995). Boulders, logs, sandbags, or gabions (rock-filled wire cages) can be used with the vegetation to provide additional stability. Structural techniques such as riprap and concrete box structures may be required in some situations; for example, to protect important resources such as roads and buildings.

Local, state, and federal permits are required for work in and along all surface waters (including lakes, streams, springs, and wetlands) and within the 100-year floodplain. This includes construction of stream crossings and impoundments, installation of riprap and other materials, and any activities which will modify the stream channel. Therefore, it is important to contact your local Soil and Water Conservation District office for assistance in planning the project and securing necessary permits before the work begins.

Riprap
Rock riprap is a method of placing stones along the streambank to stabilize the soil (Figure 7). Riprap is sometimes used to secure the base of the streambank while vegetative cuttings become established. One disadvantage to using riprap is its unnatural appearance. Riprap can also raise the temperature of the stream as the rock absorbs solar radiation. Habitat benefits can be increased by planting vegetation between the rocks.

Gabions
Gabions are rock-filled wire cages buried into the streambank to stabilize erosion (Figure 8). Gabions are especially useful for protecting banks that have been scoured or undercut. Vegetation can be planted into the bank around the gabion to increase the effectiveness and improve the appearance of the structure.

Live Cribwall
A live cribwall is a rectangular structure of logs, rocks, and woody cuttings, and filled with soil and layers of live branch cuttings (Figure 9). The cribwall is built into the streambank to protect eroding banks and is very effective on fast flowing streams. The cribwall provides long-term bank stability once the woody cuttings take root and grow. Cribwalls are not recommended where the bed is severely undercut, in rocky terrain, or on narrow reaches where banks are high on both sides.

Bank Revetments
Bank revetments are used to protect streambanks from erosion and provide overhead cover and shade for fish (Figure 10). A tree revetment is one type of bank revetment. Tree revetments are simple to construct and are made by anchoring cut trees along a streambank with wire cable. Eastern redcedar trees are commonly used and work very well because of their dense branches. Tree revetments are appropriate on small to medium banks (less than 12 feet high) that are experiencing moderate erosion. Other types of revetments may be created using boulders, root wads, and logs.

Live Stakes
Live stakes are woody plant cuttings that root quickly when placed in soil (Figure 11). Once established, they provide vegetative cover and a very effective barrier to erosion. Live stakes are economical and require minimum labor to install. Alone, they are most effective as a preventive measure before severe erosion problems develop. Live stakes may also be used to stabilize areas between other bioengineering techniques. Willow is the most commonly used material for live stakes. Table 3 lists other trees and shrubs which are suitable for use as live stakes.

Live Fascines (wattling bundles)
Live fascines are long (15 to 20 feet) bundles of live branch cuttings bound with baling twine (Figure 12). Fascines are placed in trenches along the streambank, secured with stakes, and partially covered with soil. Fascines may be constructed from cuttings of materials that are on site, such as willow, shrub dogwoods, or other species which readily sprout. Once the cuttings take root, fascines offer protection for the bank and additional stability. Fascines are particularly useful on steep, rocky slopes where digging is difficult.

Table 3. Plants suitable for use as unrooted hardwood cuttings.

Species	Region*	Tolerance to: Flooding	Drought	Deposition	Shade	Rooting Ability	Habitat Value	Form
Box elder (*Acer negundo*)	C,P,M	H**	H	H	L	L	H	small tree
Groundsel bush (*Baccharis halimifolia*)	C,P	M	M	H	L		M	large shrub
Silky dogwood (*Cornus amomum*)	P,M	L	M	L	M	H	H	small shrub
Red osier dogwood (*Cornus stolonifera*)	P,M	L	M	H	M	H	H	med. shrub
Gray dogwood (Cornus racemosa)	P,M	M	H	M	M	H	H	med. shrub
Hawthorn (*Crataegus* spp.)	C,P,M	M	H	L	L	L	M	small tree
Eastern cottonwood (*Populus deltoides*)	C,P,M	M	M	H	L	H	M	large tree
Sandbar willow (*Salix interior*)	C,P,M	H	L	H	L	L	M	large shrub
Black willow (*Salix nigra*)	C,P,M	H	H	H	L	H	M	small tree
Streamco willow (*Salix purpurea*)	C,P,M	H	M	H	L	H	H	med. shrub
Bankers willow (*Salix x cotteri*)	P,M	H	M	H	L	H	M	small shrub
American elderberry (*Sambucus canadensis*)	P,M	H	M	M	M	M	H	med. shrub
Arrowwood viburnum (*Viburnum dentatum*)	C,P,M	M	M	M	M	M	M	med. shrub
Nannyberry viburnum (*Viburnum lentago*)	C,P,M	M	M	L	M	L	M	large shrub

*C = coastal plain; P = piedmont; M = mountains.
**L = low; M = medium; H = high
From: USDA Natural Resources Conservation Service. 1992. National Engineering Handbook, Part 650 — Engineering Field Handbook Chapter 18.

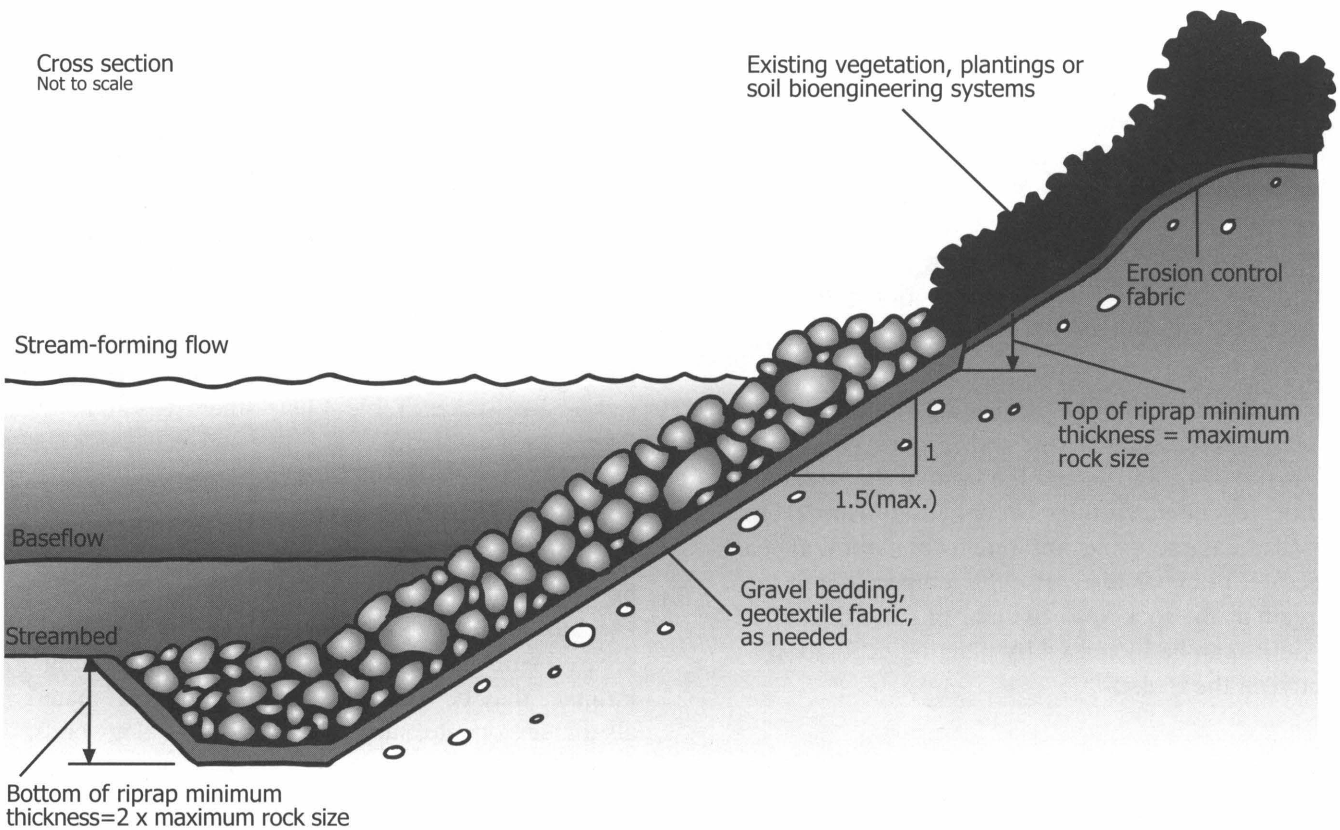


Fig 7. Rock rip-rap. (Based on illustration from USDA Natural Resources Conservation Service 1996a. Used with permission)

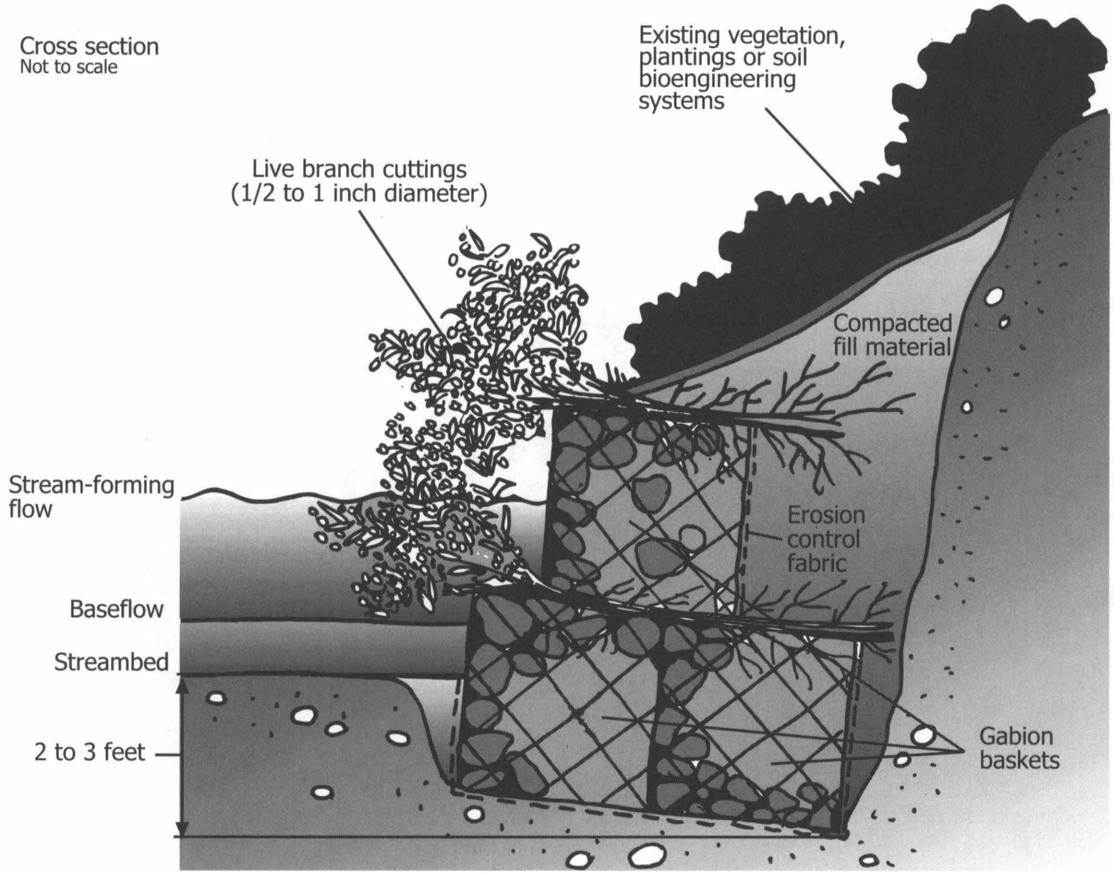


Fig 8. Vegetated rock gabion. (Based on illustration from USDA Natural Resources Conservation Service 1996a. Used with permission)

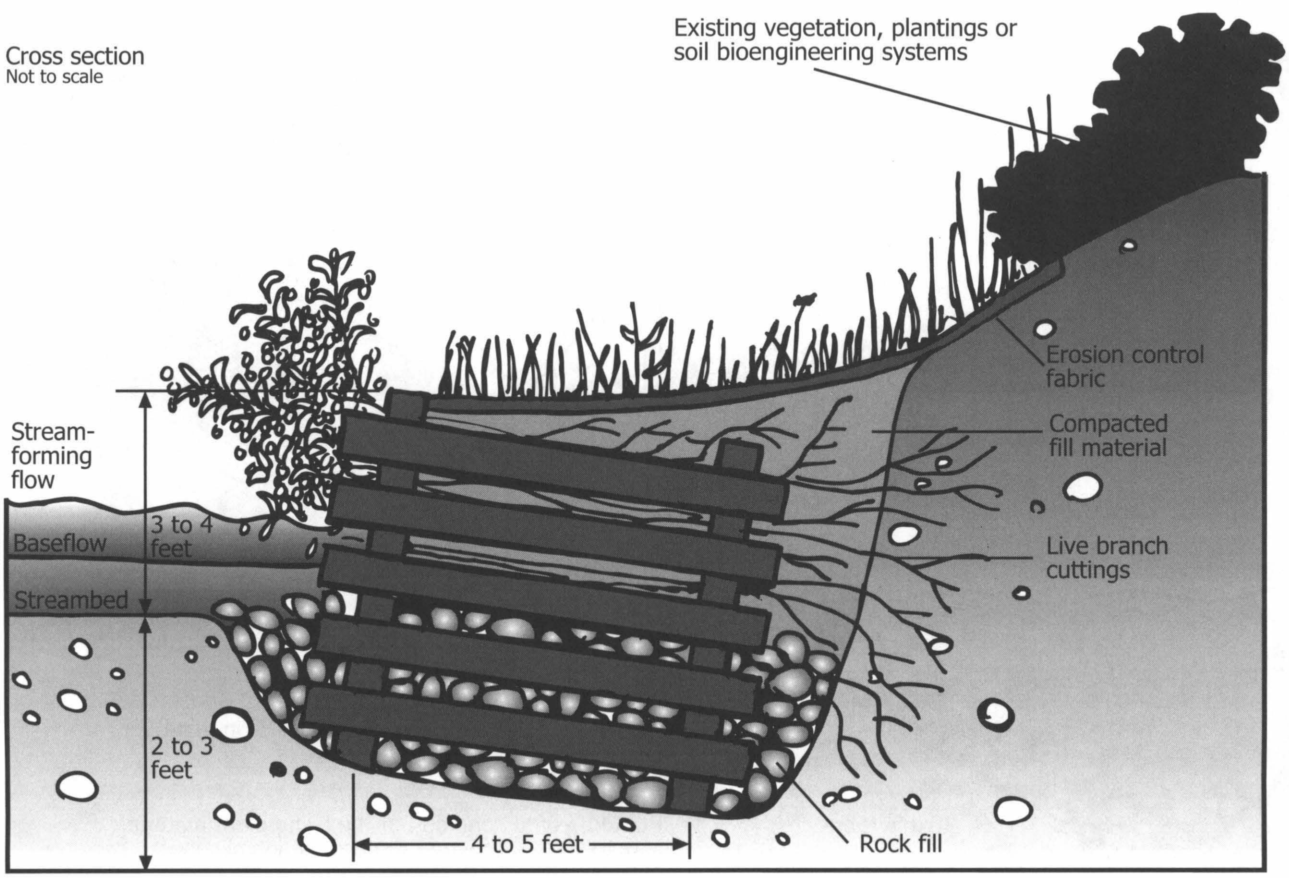


Fig 9. Live cribwall. (Based on illustration from USDA Natural Resources Conservation Service 1996a. Used with permission)

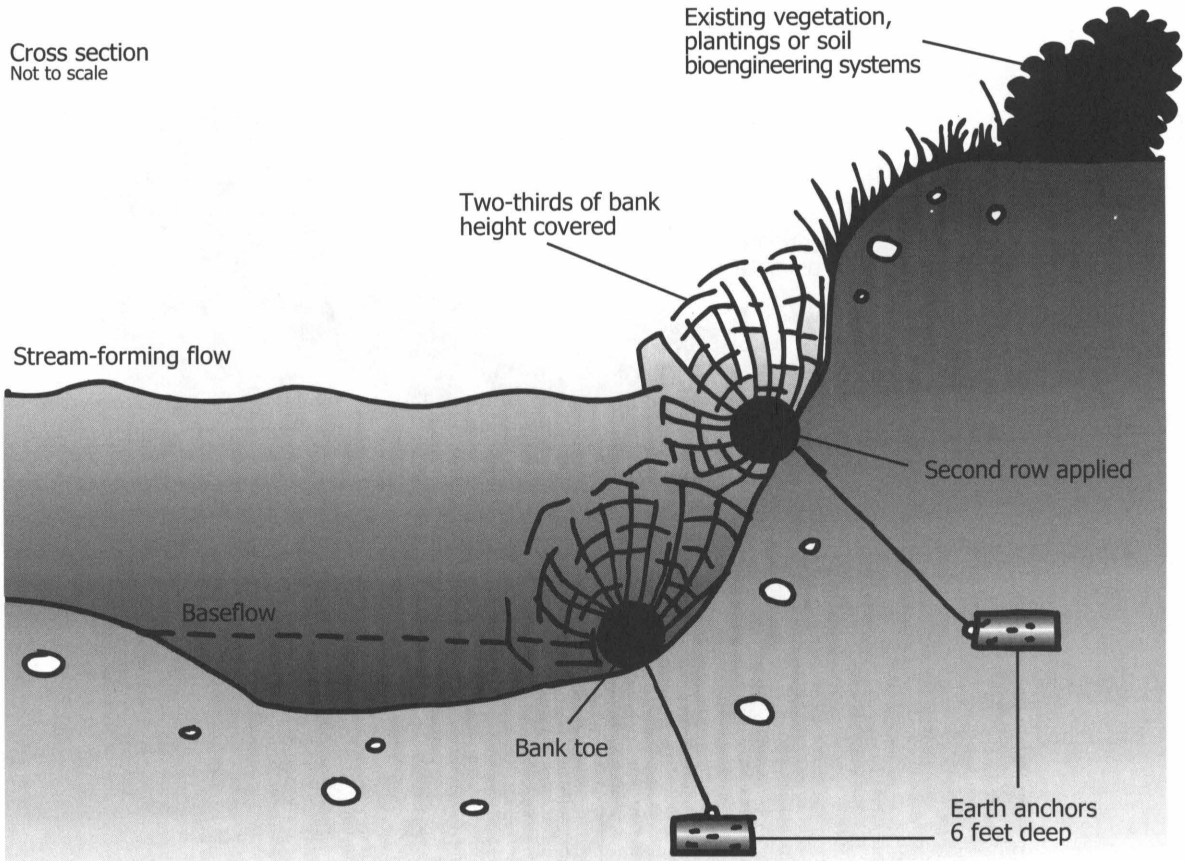


Fig 10. Bank revetments. (Based on illustration from USDA Natural Resources Conservation Service 1996a. Used with permission)

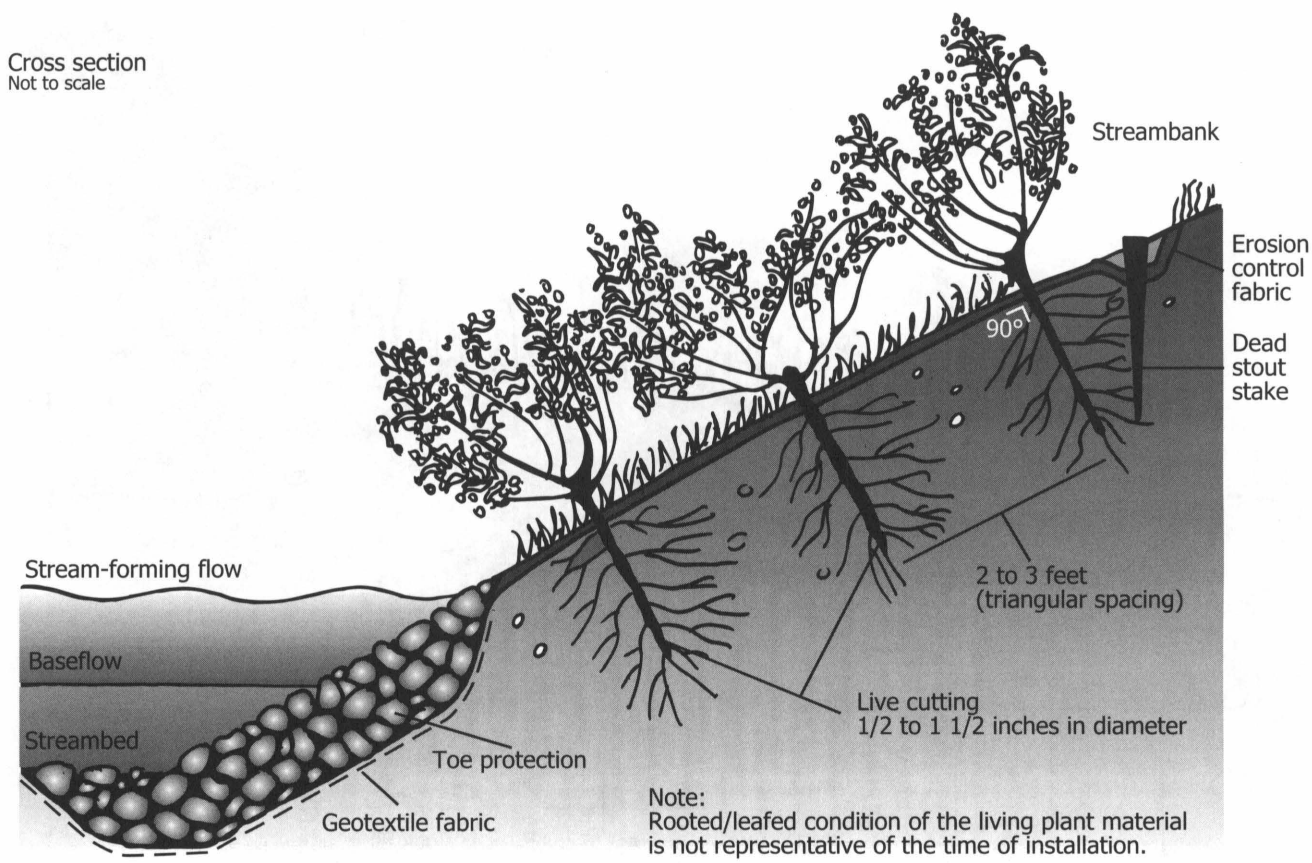


Fig 11. Live stakes. (Based on illustration from USDA Natural Resources Conservation Service 1996a. Used with permission)

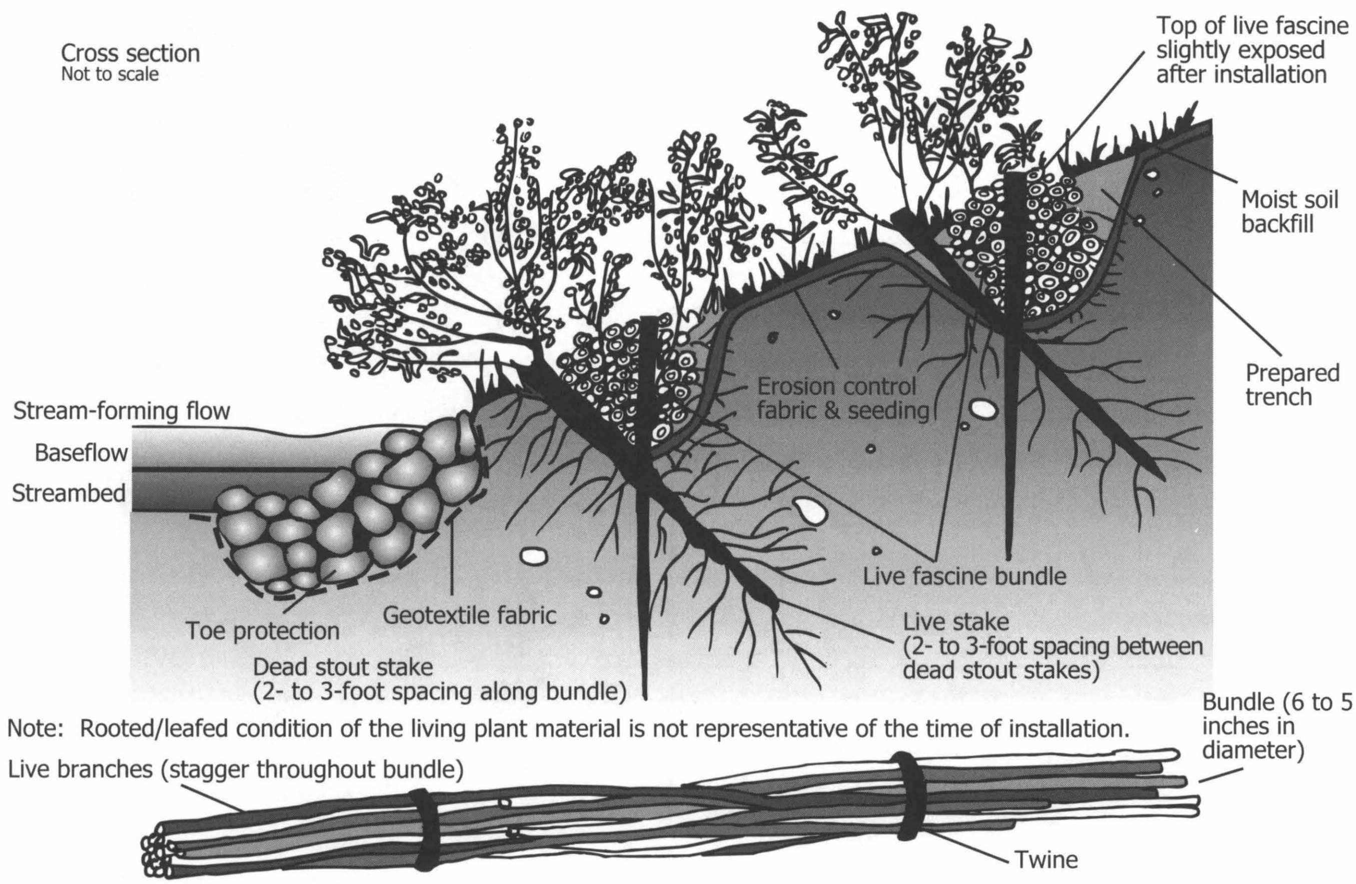


Fig 12. Live fascines. (Based on illustration from USDA Natural Resources Conservation Service 1996a. Used with permission)

Branchpacking

Branchpacking involves placing alternating layers of live branches and soil into a washed-out streambank (Figure 13). Branchpacks may be used both underwater and above fast-moving water. Branchpacks form an effective barrier that redirects water away from banks, and are often used for revegetating holes scoured in streambanks.

Brush Mattress

A brush mattress is a blanket of long branch cuttings wired together and secured to the streambank with stakes (Figure 14) (Hoffman and others 1998). The brush mattress covers the bank and provides protection immediately after it is established. Brush mattresses are very effective at capturing sediment and rebuilding an eroding bank. Once the plants take root, they provide long-term erosion control and dense plant growth. Brush mattresses, however, require a great deal of live material and are time-consuming to install.

Lunker Structure

Lunker structures are crib-like structures of wood planks and blocks held in place with reinforcing rods (Figure 15). Lunker structures are commonly used in trout streams and small warm-water streams to provide bank stabilization and in-stream cover for fish.

Log-spur Bank Feature

A log spur bank feature is constructed by partially burying the top of a large cut tree in the stream channel with the lower branches pointing into the current. The lower half of the tree lies on the bottom of the stream and is anchored by boulders along the stream bottom. Log-spur bank features are designed to stabilize the stream channel and provide in-stream habitat for aquatic organisms.

Deflectors

Deflectors are triangular, rock-filled structures used to divert the flow of water in the stream channel (Figure 16). They are used to narrow a stream channel, increase flow velocity, divert water from a bank, or to create pools. Deflectors are commonly made of a log triangle that is secured to the stream bottom with steel pins. Deflectors are best suited for low-gradient streams where water levels are stable.

Site Preparation

After the streambank has been stabilized, vegetation can be planted in the riparian area. However, site preparation is usually required before planting begins

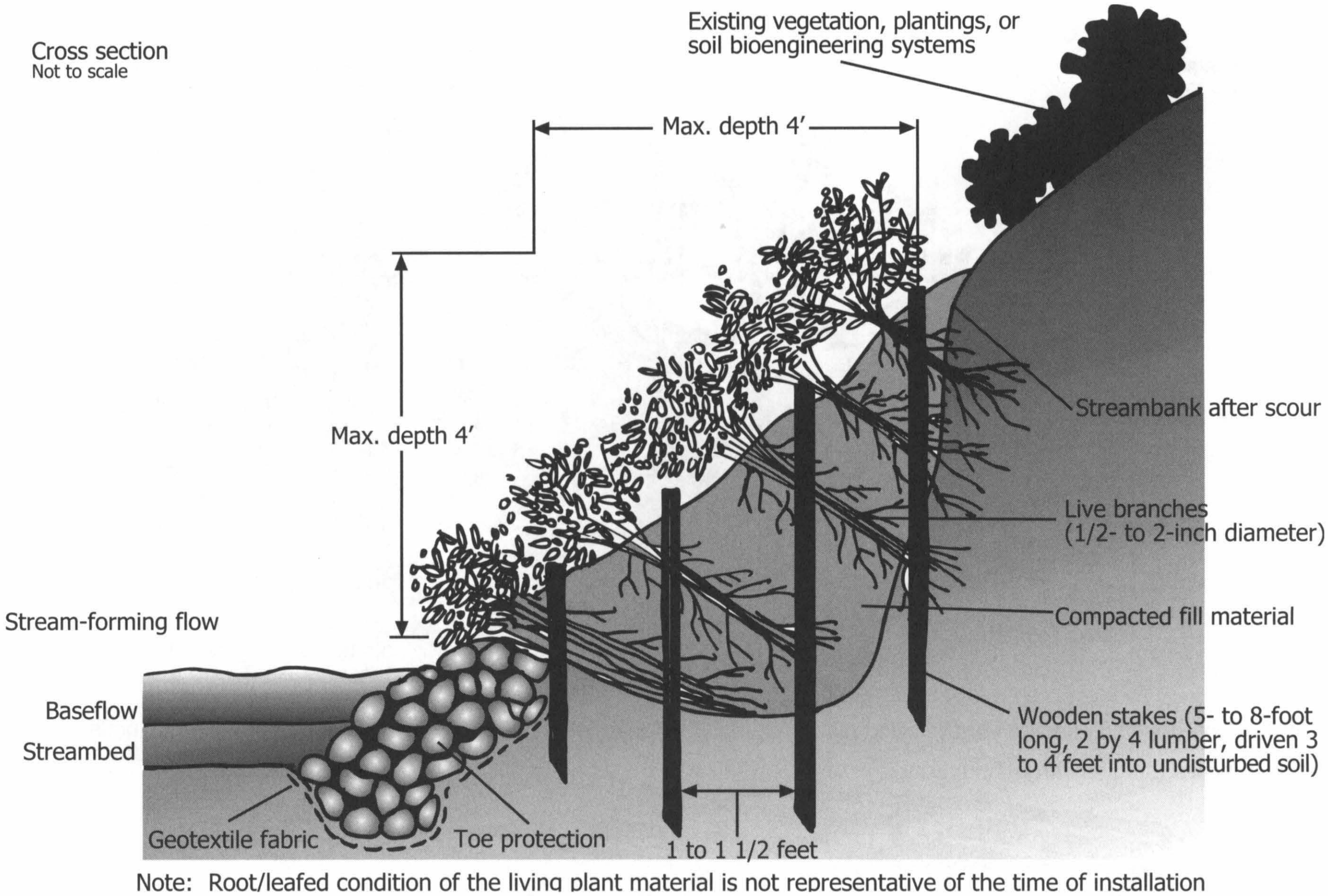


Fig 13. Branchpacking. (Based on illustration from USDA Natural Resources Conservation Service 1996a. Used with permission)

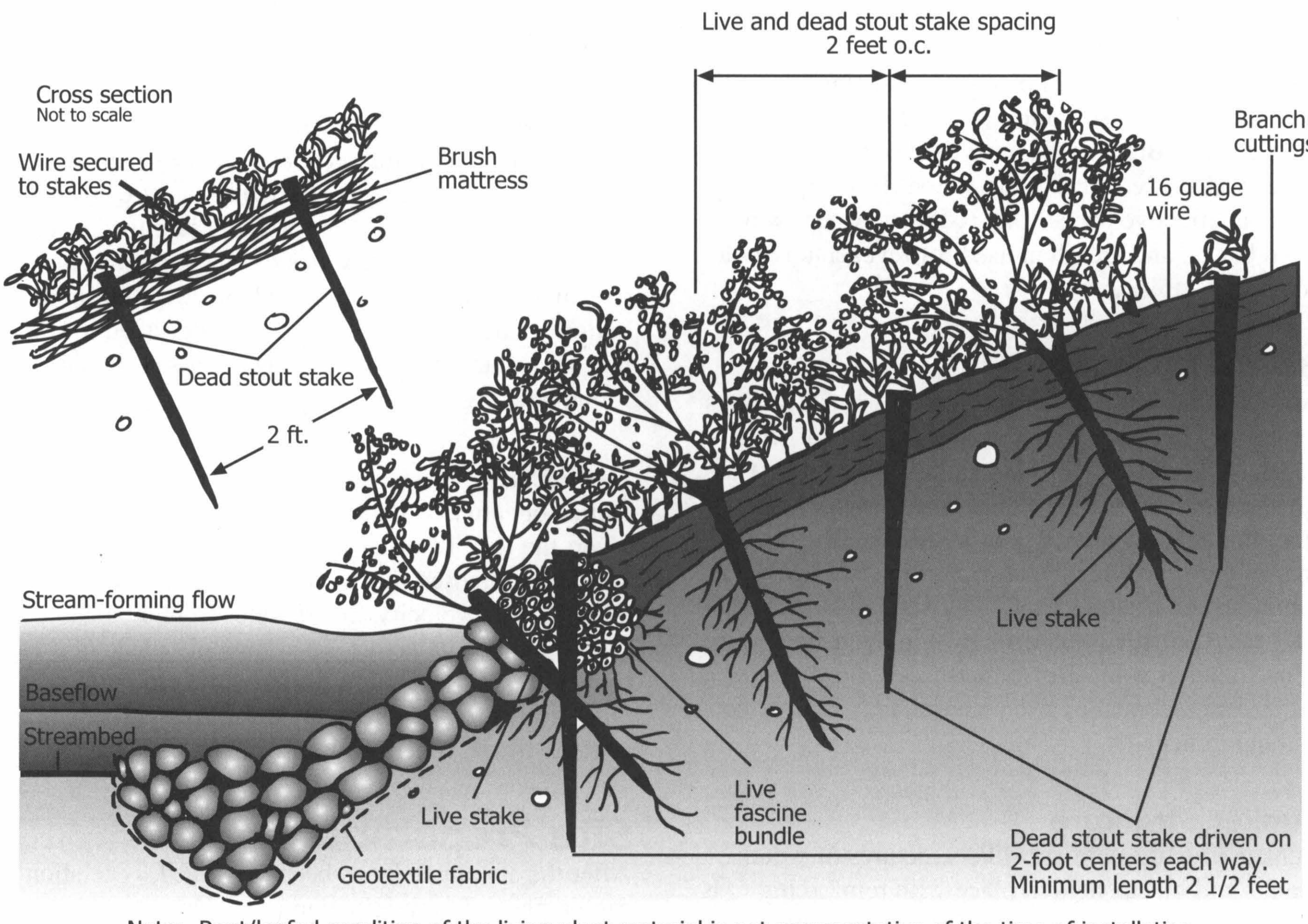


Fig 14. Brush mattress. (Based on illustration from USDA Natural Resources Conservation Service 1996a. Used with permission)

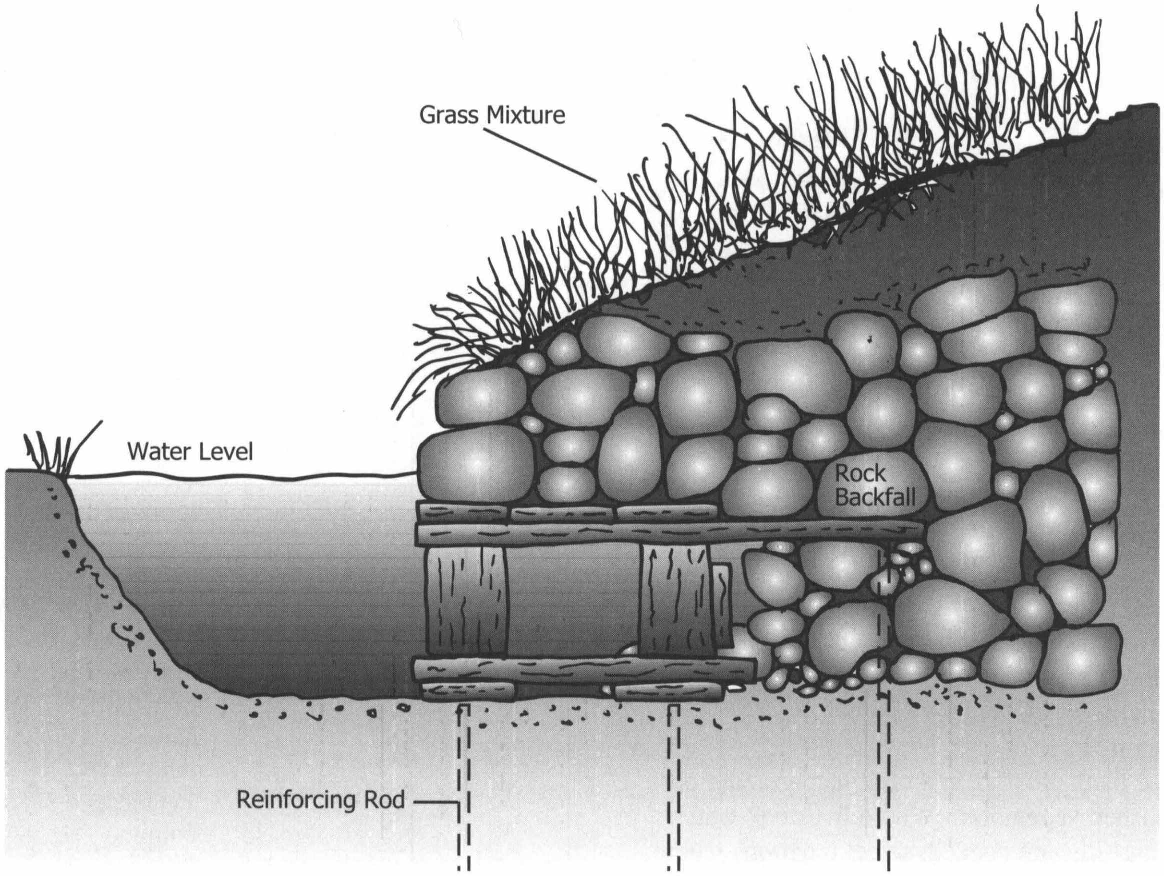


Fig 15. Lunker structure. (Based on illustration from Vetrano 1988. Used with permission)

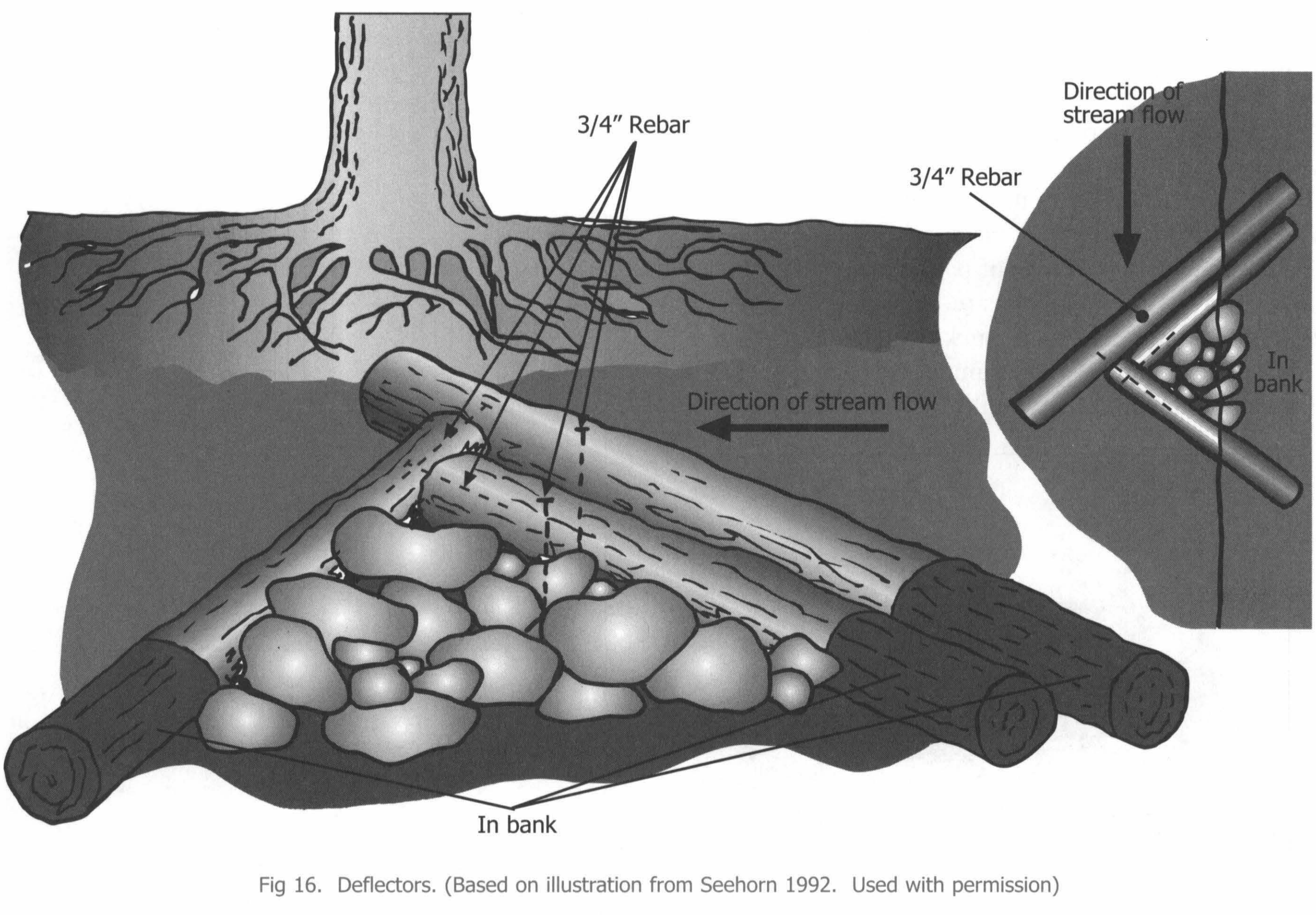


Fig 16. Deflectors. (Based on illustration from Seehorn 1992. Used with permission)

(Figure 17). The degree of site preparation needed will depend on the type of vegetation found on the site and the presence of invasive exotic weeds. If livestock have access to the riparian zone, they should be fenced out before the area is revegetated. Fencing livestock from the stream will help stabilize streambanks, reduce bank erosion, and eliminate grazing on newly established vegetation. Where livestock watering or crossing sites are needed, select locations where there are smooth, low slopes and hard bottoms. Stone can be spread on entrance ramps to the stream to minimize streambank damage, and swinging flood gates or polywire can be erected across the stream to restrict livestock movement upstream and downstream.

Fig 17. The site must be prepared before planting. Here, the area has been mown and a band of herbicide is applied at planting.

If invasive weeds are a problem, it is important to control them before the vegetation is planted (Palone and Todd 1997). Where the problem is severe, this can require as much as a year of successive treatments (Figure 18). Weeds of particular concern in riparian areas are phragmites (common reed), oriental bittersweet, Japanese honeysuckle, kudzu, porcelain berry, mile-a-minute vine, trumpet creeper vine, Japanese bamboo, privet, multiflora rose, tree-of-

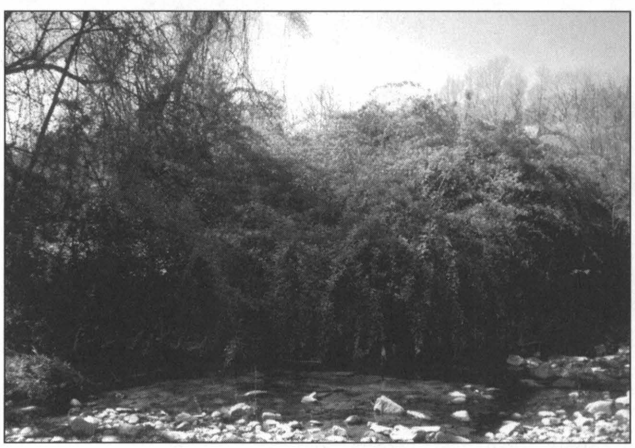


Fig 18. Invasive weeds can hinder restoration efforts in riparian areas and should be controlled prior to planting.

Table 4. Herbicides for invasive plant control.

Herbicide	Trade Name	Target Species
Clopyralid	Transline®	Kudzu
Diacamba	Veteran CST®	Trees (apply to cut stumps or inject)
Fosamine	Krenite S®	Multiflora rose; tree-of-heaven
Glyphosate	Accord®	Sod
	Compadre®	Multiflora rose
	Rodeo®	Kudzu
	Roundup®	Japanese bamboo Trees (poor control of maple, holly, hickory, and blackgum)
Imazapyr	Arsenal®	Turf grasses, trees
	Chopper®	(blackberry, locust, pine, hickory, dogwood, redbud, and elm are resistant)
	Arsenal® + glyphosate	Japanese bamboo
	Chopper® +	Phragmites
	Accord®	Locust and pine are resistant
Metsulfuron	Escort®	Kudzu Multiflora rose Blackberry
	Escort® + Garlon 3A®	Oriental bittersweet Porcelain berry Poison ivy Wild grape Blackberry Multiflora rose
Sulfometuron	Oust®	Turf grasses (poor control of broomsedge and wire grass)
	Oust® + glyphosate	Turf grasses
Triclopyr	Pathfinder II®	Wild grape
	Garlon®	Poison ivy Dicots and broadleaf plants (maple resistant)

From: Palone, R. S., and A. H. Todd (eds.). 1997. Chesapeake Bay riparian handbook: A guide for establishing and maintaining riparian forest buffers. USDA Forest Service NA-TP-02-97.

Virginia Department of Forestry. 1999. Herbicide Use Sheets — Program Year 1999. http://www.dof.state.va.us/mgt/herbuse.htm. Virginia Department of Forestry, Charlottesville.

heaven, and Norway maple. Invasive weeds can be controlled by either mechanical or chemical means. Examples of mechanical control are mowing multiple times over the growing season to exhaust root systems, ripping them out with a tractor, or girdling the plants. However, these weeds are persistent and can be difficult to control with mechanical methods. Chemical control with herbicides are recommended in areas where they can be safely applied. Herbicides may pose a danger to aquatic life, therefore, it is important to follow the label carefully. Herbicides labeled for use in riparian areas are listed in Table 4; contact the Virginia Department of Forestry for additional recommendations.

After weeds are controlled, the ground should be prepared for tree planting. If the ground is in pasture, the area should be plowed, disked (up to three feet from the stream), and sprayed with an herbicide to control weeds. A cover crop (such as annual rye, field bromegrass, or a mixture of switchgrass, deertongue, eastern gamagrass, and smartweed in wet areas) should be planted to stabilize the soil. If vines are a problem in the area, legumes such as lespedeza and birdsfoot trefoil should be planted as a cover crop.

On certain sites where erosion is likely, it is better to leave the sod in place and spray a small area (about a four-foot-diameter circle) with an herbicide where the seedling will be planted (Palone and Todd 1997). Weeding and mowing will be necessary the first three years or until the trees are established.

In some cases, the riparian area may already have established shrubs and trees of desirable species. In this case, a timber stand improvement may be needed to release the trees from competition and to remove less desirable vegetation. A timber stand improvement can be accomplished by cutting, girdling, or injecting the undesirable plants with a herbicide. The best time to treat the site is just after the plant has leafed out in the spring (usually around late May). At this time, root reserves are low, which reduces the plant's ability to resprout (Palone and Todd 1997).

Establish Vegetation

Naturally vegetated riparian areas are among the most productive and diverse plant communities. However lush, this vegetation has adapted to wide fluctuations in water levels and regular disturbances (Figure 19). Therefore, it is important to select the proper plant species when revegetating riparian areas. An important factor to consider is the riparian area hydrology, particularly the depth to the water table and the frequency, season and duration of flooding (McKevlin 1992). Soil characteristics such as soil type, texture,

Fig 19. Riparian vegetation must tolerate frequent disturbance and flooded conditions.

structure, and pH are all important considerations. Keep in mind that soils and hydrology can be highly variable within the same floodplain.

Trees planted on the streambank should be selected for their ability to withstand frequent disturbance and flooded conditions. These trees must also provide bank stability, a dense canopy for shade, and food for aquatic organisms. Native species that are fast-growing and easily established are good choices here. Examples include river birch, black willow, red maple, eastern cottonwood, green ash, and sycamore (Hupp 1992, Palone and Todd 1997). Further back from the streambank, a wider variety of trees is recommended. Sweetgum, hackberry, water-tolerant oaks, hickories, and clumps of pine or other evergreen trees are suitable here. Pines will grow quickly and help break the wind, providing some protection for the hardwoods and cover for wildlife until the hardwood stand is established. Suitable shrubs can be placed among the trees or along the forest edge.

Table 5 lists trees and shrubs appropriate for planting in riparian areas. They may be purchased from the Virginia Department of Forestry, mail-order nurseries, and local sources (Figure 20).

Fig 20. Community tree planting.
(Photo courtesy Chesapeake Bay Program)

Table 5. Native trees and shrubs for riparian areas.

Plant Name	Region*	Flood Tolerance**	Height (ft)	Growth	Wildlife Value	Aesthetic Value
Deciduous Trees:						
American hornbeam Notes: common in bottomlands of Piedmont and mountains	P,M	L-M	30-40	slow	moderate	
Atlantic white cedar Notes: sun; cannot compete with hardwoods	C	M-H	50-75	medium	low	
Baldcypress Notes: full sun; tolerates drought; Coastal Plain species	C	H	>75	medium	little food value; perching site for waterfowl	stately form
Black walnut Notes: temporarily flooded floodplains; well-drained, deep soils	C,P,M	M	>75	slow	moderate, food	
Black willow Notes: rapid growth; stabilizes streambanks; full sun	C,P,M	H	50-75	fast	moderate, food and nesting	
Blackgum (swamp tupelo) Notes: difficult to transplant; does best in sun to partial shade	C,P,M	M-H	<50	moderate	high; food for ducks, turkey, mammals	brilliant red fall color, blue fruit
Bitternut hickory Notes: moist soils and wet bottomlands	C,P,M	M	>75	medium-slow	moderate, food	yellow fall color
Downy serviceberry (shadblow) Notes: understory tree	C,P,M	H	30-40	slow	high; food, nest, cover	early spring flower
Eastern cottonwood Notes: sun; rapid growth; shallow, invasive roots; prone to windthrow	C	H	>75	fast	moderate	yellow fall color
Eastern hophornbeam Notes: understory; tolerates all light conditions	C,P,M	M-H	40	medium	low-moderate	horticultural uses
Green ash Note: rapid growth; streambank stabilizer; good nutrient uptake; full sun to partial shade; good sawtimber tree	C,P,M	M-H	50-75	fast	low-moderate	yellow fall color
Hackberry Notes: full sun to partial shade; adaptable to a wide range of conditions	M	L	>75	medium-fast	high; fruits and twigs; cover	
Overcup oak Notes: shade-partial shade; good on poorly drained sites	C	H	65-80	slow	moderate	
Persimmon Notes: edible fruit; not shade-tolerant	C,P,M	M	<50	slow	high	red fall color

Plant Name	Region*	Tolerance**	Height (ft)	Growth	Value	Asthetic Value
Pin oak Notes: tolerates acid soils; prefers sun to partial shade; gypsy moth target	C,P,M	H	50-75	fast	high	bronze or red fall foliage
Red maple Notes: tolerates acidic soils; rapid growth	C,P,M	H	50-75	fast	high; seeds	red fall color and spring bloom
Red mulberry	C,P,M	M	50-75	fast	high	yellow fall color
River birch Notes: bank erosion control; full sun	C,P,M	H	50	slow-medium	low-medium; provides cavities and some food	unique peeling; reddish bark
Swamp chestnut oak Notes: grows well in bottomlands; good sawtimber species	C,P	H	>75	medium	high	full sun to partial shade
Swamp white oak Notes: partial shade; grows well on poorly drained soils; long-lived	C,P,M	H	60-70	fast	high; ducks, woodpecker, turkey	
Sweetbay Notes: part shade	C	H	50	slow	low	horticultural uses
Sweetgum Notes: sun to partial shade; tolerates acidic, clayey soils	C,P,M	L-M	50-75	medium-fast	low	excellent fall color; interesting seed pod
Sycamore Notes: rapid growth; common on floodplains	C,P,M	M	>75	fast	low; provides cavities	unique white peeling bark; interesting seed pod
Water oak Notes: shade-partial shade; does not tolerate standing water; sprouts readily	C	H	50-80	slow	moderate-high in the South	common landscape tree
Willow oak Notes: full sun to partial shade; common in forested wetlands	C,P	M-H	>75	fast	high	ornamental
Yellow (tulip) poplar Notes: full sun to partial shade; well drained soils; rapid growth; high nutrient uptake	C,P,M	L	>75	fast nest sites	moderate-low; attractive flower	yellow fall color;
Evergreen trees:						
Eastern hemlock Notes: tolerates acidic soil; all light conditions	M	M-H	>60	slow-med	moderate; good cover, winter food	attractive form
Loblolly pine Notes: tolerant of extreme soil conditions; Coastal Plain species; fast growth	C,P	L	>75	fast	moderate	

Plant Name	Region*	Tolerance**	Height (ft)	Growth	Value	Asthetic Value
Shrubs:						
Arrowwood viburnum Notes: sun to partial shade; suckers freely	C,P,M	M	10	medium	moderate-high	
Bayberry (wax myrtle) Notes: tolerates slightly acidic soil; roots fix N; sun	C	H	40	medium	high; cover, nesting, persistent berries	
Buttonbush Notes: full to partial shade; will grow in dry areas	C,P,M	H	10	fast	moderate; ducks, nectar for hummingbirds	unusual round white flowers
Common (smooth) alder Notes: stabilizes streambanks, fixes N; full sun	C,P,M	H	25	medium-fast	low-moderate	
Elderberry Notes: full sun; edible berries used for pies, jelly, wine	C,P,M		3-12	fast	high; important food for many birds	white fragrant flowers; purple clusters of fruit
Gray dogwood	P,M	L	10	medium	high	white flowers; white berries
Highbush blueberry	C,P,M	H	12	slow	high	sun to partial shade
Ninebark Notes: sun	C,P	H	9	fast	low-med	peeling bark hidden by dense foliage
Pawpaw Notes: suckers and forms colonies; shade	C,P,M	M	30-40	medium-fast	high; food for turkey and mammals	attractive flower
Red chokeberry Notes: bank stabilizer; partial sun	C,P,M	M	20		moderate; food and cover	
Silky (swamp) dogwood Notes: bank stabilizer; shade- and drought-tolerant	C,P,M	M	10	fast	high; berries and twigs	white flower, blue berry
Spicebush Notes: understory; tolerates acidic soils; shade and rich soils	C,P,M	M	9	fast	high; rabbit, opossum, birds	fragrant leaves and twigs, yellow fall color
Swamp azalea Notes: shade	C,P	H	17	medium	low	glossy leaves, white-pink flower
Sweet pepperbush Note: sun to partial shade	C	H	15	medium	high	sweetly scented flower
Virginia willow (sweetspire) Notes: sun to partial shade	C	H	10	medium-slow	low	attractive flower spears
Winterberry Notes: full sun to partial shade; seasonally flooded areas; need male and female plants for fruit production	C,P,M	M-H	25	slow	high; cover and food, holds berries in winter	attractive berries held through winter, some times gathered for Christmas
Witch hazel Notes: prefers shade	P,M	L	25	slow	low; food for squirrel, ruffed grouse	unusual fall flower and fruit

*C = coastal plain; P = piedmont; M = mountains
**H = high; M = moderate; L = low

From:
1) Tjaden, R. L., and G. M. Weber. 1997. Trees for riparian forest buffers. Maryland Cooperative Extension Service Fact Sheet 726. College Park, MD.
2) USDA Natural Resources Conservation Service 1996. Maryland Conservation Practice Standard: Riparian Forest Buffer Standard. USDA-NRCS, Annapolis, MD.
3) Palone, R. S., and A. H. Todd (eds.). 1997. Chesapeake Bay riparian handbook: A guide for establishing and maintaining riparian forest buffers. USDA Forest Service NA-TP-02-97.
4) Elias, T. S. 1980. The complete trees of North America. Outdoor Life/Nature Books. Van Nostrand Reinhold Co., NY.

Planting bare-root tree seedlings usually provides the best result for most species (McKevlin 1992). Trees should be planted at about 110 trees per acre, or about 20 feet apart. Understory shrubs can be planted 5 to 8 feet apart between the trees. Trees and shrubs should be planted in late fall or spring, while they are dormant. Take care to prevent the trees from drying out and store away from direct sunlight. Deciduous trees should be placed in a hole two to three times wider than their roots and no deeper than their roots. The roots should be spread out in the hole and soil firmly packed around to eliminate air pockets. Water trees as necessary.

Direct seeding of species with large seeds (such as black walnut, hickory, and oak) is an option, but is rarely used. Seeds should be planted 2" deep at a rate of 1500 per acre (approximately 3' x 10' spacing) (McKevlin 1992). Trees or seeds that are protected by tree shelters may regenerate more successfully (Figure 21). However, tree shelters can be knocked down during floods or high winds, and must be straightened. Tree shelters are also expensive, at a cost of $2-$3 each. In urban environments, the use of larger balled and burlap trees or containerized stock is appropriate. Recommended spacing for these trees is 16' apart, or 200 trees per acre (Palone and Todd 1997).

Fig 21. Tree shelters help protect seedlings from wildlife, mowers, and herbicide treatments.

Native warm-season grasses, such as switchgrass and eastern gamagrass, are often recommended for the portion of the buffer planted to grass (Zone 3) (Figure 22). Warm-season grasses are preferred due to their large root systems, high above-ground productivity, value to wildlife, and low maintenance (Schultz and others 1995). Table 6 lists warm-season grasses appropriate for Zone 3. Where sediment loads are low (less than 1000 lb/ac/yr), herbaceous forbs and shrubs may be included in Zone 3 (Palone and Todd 1997).

Warm-season grasses are established by plowing, disking, and cultipacking the area to create a firm seedbed (Capel 1992). Seed is drilled into the soil (1/4" deep) with a small grain drill (using the alfalfa seed box) or broadcast with a cyclone spreader, and cultipacked to tamp down the seed. Chaffy seeds or seeds with wings (for example, Bluestem and Indiangrass) are usually broadcast because they clog the drill. Warm-season grasses should be planted when the soil is >60°F (April to June in the Coastal Plain and May to early July in other parts of the state), and if possible, just prior to a good rain (Wolf and Fiske 1995). Nitrogen fertilizer is not recommended at seeding; phosphorus, potassium, and lime should be applied if recommended according to soil test recommendations. Grass seed should be purchased on a Pure Live Seed (PLS) basis rather than by bulk weight (Pure Live Seed accounts for debris and germination efficiency). A high Pure Live Seed is a good indication of overall seed quality.

Fig 22. Warm season grasses are recommended in Zone 3 of the buffer. (Photo by Martin van der Grinten, courtesy USDA-NRCS)

Maintenance

Riparian buffers require ongoing maintenance to remain effective. The landowner should walk the area on a regular basis, watching for damage to fences, the formation of gullies, weed problems, wildlife damage, insect and disease problems, bank erosion and wash-outs in the stream. Some seedling mortality is expected; however, if stand density falls below 80 trees per acre, reinforcement plantings will be needed (Figure 23).

During buffer establishment, competition for light and nutrients from weeds can cause mortality and substantially reduce seedling growth. Weeds should be controlled by mowing, mulching, or herbicides (Figure 24). Mowing may effectively control weeds on some sites, particularly if mowed on a regular basis. However, mowing can damage tree seedlings and where weeds are thick, does not eliminate the competition for moisture. Mowing also requires that

Table 6. Native warm-season grasses for riparian buffers.

Grass	Suggested Varieties	Height (feet)	Where Found	Soil Preference	Flood Tolerance	Drought Tolerance	Wildlife Value
Big bluestem Notes: Valuable forage as pasture and hay; valuable in ornamental plantings and xeriscapes	Niagara	6' - 8', roots to 8'	Moist meadows, river banks	Loamy soils, moderate drainage or better. Grows well on acid, droughty, low fertility sites	Fair	Good	Good
Coastal panicgrass Notes: Good for sand dune stabilization, reclaimed minelands and wind barriers	Atlantic	3' - 6', roots 6'+	Sandy shores, alluvium, banks	Sand to loam	Good	Good	Food for rabbit, muskrat, deer, wild turkey, ducks, geese
Eastern gamagrass Notes: Most productive, nutritious grass for producing livestock forage warm-season	Pete	8'	Open fields, swamps, wet shores	Moderately well drained to poorly drained soils	Very good		
Indiangrass Notes: Ornamental value; good for erosion control on droughty sites	Rumsey	3' - 8'	Moist or dry fields, roadsides	Wide range of soil types Prefers deep, well-drained floodplain soils	Poor	Good	Food and cover
Little bluestem Notes: Occurs throughout Virginia; low maintenance cover highly recommended for droughty sites	Aldous, Camper, Blaze	1.5' - 3', roots to 7'	Roadsides, open woods	Sand to loam; does well on droughty sites	Poor	Good	Good
Switchgrass Notes: Long-lived; useful as forage and wind barrier; under study for use as energy biomass	Alamo, Kanlow, Cave-in-Rock	3' - 8', roots to 12'	Sandy shores, alluvium, banks	Loam to sand, well adapted to a variety of soil types	Good	Good	Food for rabbit, muskrat, deer, wild turkey, ducks, geese; excellent spring nesting habitat

From: USDA Natural Resources Conservation Service. 1997. Grasses that can be used for planting in riparian forest buffers and herbaceous buffers. USDA-NRCS Conservation Plant Sheets for the Northeast. USDA-NRCS, Annapolis, MD.

USDA Natural Resources Conservation Service. 1996. National Engineering Handbook, Part 650 — Engineering Field Handbook Chapter 16 — Streamline and Shoreline Protection. USDA NRCS, Washington, DC.

Fig 23. Reinforcement plantings may be necessary if seedling survival is low.

Fig 24. Weed should be controlled by mowing, mulching, or herbicides.

trees are planted on a more regular spacing. Mulches or weed control fabrics can be an alternative to mowing, and provide the additional benefit of protecting trees from moisture stress in drought-prone areas. Herbicides probably offer the best control for competition and result in more rapid establishment of the forest buffer. Tree shelters can increase survival of tree seedlings and protect seedlings during mowing or spraying.

After the trees are established, the trees should be periodically thinned to maintain vigorous growth and maximize nutrient uptake (Palone and Todd 1997). Selective harvest of mature trees is recommended to sustain adequate growth and remove nutrients sequestered in tree stems and branches. During harvest, care should be taken to protect the forest floor from disturbance and compaction and to preserve surface and subsurface water flows (Nutter and Gaskin 1988).

Following forestry Best Management Practices (BMPs) during harvest accomplishes these objectives. BMPs for logging in riparian areas are described in the "Forestry Best Management Practices Guide for Virginia," issued by the Virginia Department of Forestry (1997). Best Management Practices that apply in streamside areas include:

- Harvesting should remove no more than 50% of the crown cover and should be limited to cable or winch systems.
- Log decks, sawmill sites, and drainage structures should not be constructed inside the riparian area.
- Stream crossings should be avoided wherever possible. If a stream crossing is necessary, a temporary bridge, culvert, or ford should be installed. A permit is required to construct a stream crossing over a stream which drains more than a 3000-acre area.
- Any wetlands, bogs, or seeps found in the riparian area should receive special protection.
- Trees should be felled away from the seeps and wetlands, and should not be skidded through the area.
- The movement or entry of equipment into these areas should be avoided wherever possible.

To plan a successful tree harvest, first consult the Virginia Department of Forestry. By law, they *must* be notified that a harvest will occur three days before logging begins. Be aware that additional federal, state, and/or local regulations may apply to activities in wetland areas; therefore, the local office of the U.S. Army Corps of Engineers should be contacted before any activity occurs in a wetland area.

Warm-season grasses that are incorporated into the buffer plan will also require regular maintenance (Dillaha and Hayes 1991, Capel 1992). These grasses are slow to establish and spend the first two years developing their deep root systems. During this time, the grass stand will require regular mowing or herbicide application to control broadleaf weeds. Once established, periodic controlled burns (about every 3 to 4 years) can help warm-season grasses recycle nutrients, stimulate new growth, and kill back woody plants and other species. Warm-season grasses have few insect or disease problems and do not normally require fertilizer.

As sediments accumulate in the buffer, they may create a small berm between the buffer and the field edge. The berm will eventually prevent field runoff from flowing through the buffer and cause runoff to flow parallel to the buffer instead. Where this occurs, accumulated sediments should be removed and the area regraded and reseeded. In areas of moderate erosion, this will occur about every 10 years, or when more than 6” of sediments have accumulated.

How Long to Recovery?

Once a forested riparian buffer is established, it begins to provide some important functions after only a few years (Figure 25). For example, in Iowa researchers found that a newly established buffer trapped 80-90% of sediments and up to 90% of nitrates and atrazine from field runoff by the fourth growing season (Schultz and others 1995). In the southeastern Coastal Plain, researchers observed that in high organic matter soils and where anoxic sediments are present, buffers begin to have a major impact on nitrate in five to ten years (Lowrance and others 1997). However, in other areas, 15 to 20 years may be required before buffers begin to control nitrate loads.

Wildlife use of the area will change throughout the life of the buffer. In Virginia, wildlife biologists observed significant use of streamside areas by birds within five to nine years after they had been cleared and allowed to revegetate naturally (Ferguson et al 1975). They expected that bird species diversity would continue to increase as the stand matured and became more structurally complex. The aquatic community will benefit immediately from improved water quality. However, benefits such as stream cooling and inputs of large woody debris will occur only slowly, over many years.

Fig 25. Benefits to the stream are gradually restored.

List of Common and Scientific Names

American hornbeam	*Carpinus caroliniana*
Annual rye	*Secale cereale*
Arrowwood viburnum	*Viburnum dentatum*
Atlantic white cedar	*Chamaecyparis thyoides*
Baldcypress	*Taxodium distichum*
Bald eagle	*Haliaeetus leucocephalus*
Bayberry (wax myrtle)	*Myrica cerifera*
Big bluestem	*Andropogon gerardi*
Birdsfoot trefoil	*Lotus corniculatus*
Bitternut hickory	*Carya cordiformis*
Black walnut	*Juglans nigra*
Black willow	*Salix nigra*
Blackberry	*Rubus spp.*
Blackgum	*Nyssa sylvatica*
Bluestem	*Andropogon spp.*
Bromegrass	*Bromus spp.*
Broomsedge	*Andropogon virginicus*
Buttonbush	*Cephalanthus occidentalis*
Coastal panicgrass	*Panicum amarulum*
Common (smooth) alder	*Alnus serrulata*
Deertongue	*Panicum clandestinum*
Dogwood	*Cornus spp.*
Downy serviceberry (shadblow)	*Amelanchier arborea*
Eastern cottonwood	*Populus deltoides*
Eastern gamma grass	*Tripsacum dactyloides*
Eastern hemlock	*Tsuga canadensis*
Eastern hophornbeam	*Ostrya virginiana*
Eastern red cedar	*Juniperus virginiana*
Elderberry	*Sambucus canadensis*
Elm	*Ulmus spp.*
Grape	*Vitus spp.*
Gray dogwood	*Cornus racemosa*
Green ash	*Fraxinus pennsylvanica*
Greenbriar	*Smilax rotundifolia*
Hackberry	*Celtis occidentalis*
Hickory	*Carya spp.*
Highbush blueberry	*Vaccinium corymbosum*
Holly	*Ilex spp.*
Indiangrass	*Sorghastrum nutans*
Japanese bamboo	*Phyllostachys species*
Japanese honeysuckle	*Lonicera japenica*
Kudzu	*Pueraria montana var. lobata*
Lespedeza	*Lespedeza spp.*
Little bluestem	*Schizachyrium scoparium*

Loblolly pine	*Pinus taeda*
Locust	*Robinia spp.*
Maple	*Acer spp.*
Mile-a-minute	*Polygonum perfoliatum*
Multiflora rose	*Rosa multiflora*
Ninebark	*Physocarpus opulifolius*
Norway maple	*Acer platanoides*
Oak	*Quercus spp.*
Oriental bittersweet	*Celastrus orbiculatus*
Overcup oak	*Quercus lyrata*
Pawpaw	*Asimina triloba*
Persimmon	*Diospyros virginiana*
Phragmites	*Phragmites communis*
Pin oak	*Quercus palustris*
Pine	*Pinus spp.*
Poison ivy	*Toxicodendron radicans*
Porcelain berry	*Ampelopsis brevipendunculata*
Privet	*Ligustrum spp.*
Red chokeberry	*Aronia arbutifolia*
Red maple	*Acer rubrum*
Red mulberry	*Morus rubra*
Redbud	*Cercis canadensis*
River (black) birch	*Betula nigra*
Silky (swamp dogwood)	*Cornus amomum*
Smartweed	*Polygonum spp.*
Spicebush	*Lindera benzoin*
Swamp azalea	*Rhododendron viscosum*
Swamp chestnut oak	*Quercus michauxii*
Swamp white oak	*Quercus bicolor*
Sweet pepperbush	*Clethera alnifolia*
Sweetbay	*Magnolia virginiana*
Sweetgum	*Liquidambar styraciflua*
Switchgrass	*Panicum virgatum*
Sycamore	*Platanus occidentalis*
Tree-of-heaven	*Ailanthus altissima*
Trumpet creeper vine	*Campsis radicans*
Virginia willow (sweetspire)	*Itea virginica*
Water oak	*Quercus aquatica*
Willow	*Salix spp.*
Willow oak	*Quercus phellos*
Winterberry	*Ilex verticillata*
Wiregrass	*Juncus spp.*
Witch hazel	*Hamamelis virginiana*
Yellow (tulip poplar)	*Liriodendron tulipifera*

Additional Resources

General References

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Riparian forests are forests which occur adjacent to streams, lakes, and other surface waters. Through the interaction of their soils, hydrology, and biotic communities, riparian forests protect and improve water quality, provide habitat for plants and animals, support aquatic communities, and provide many benefits to humans. Virginia, along with other states in the Chesapeake Bay region, has recognized the importance of riparian forests by implementing a plan to restore forested buffers along streams, rivers, and lakes. This series of publications by Virginia Cooperative Extension reviews selected literature on riparian forest buffers, including water quality functions, benefits to fish and wildlife, and human benefits. The review also discusses riparian buffer restoration and some of the costs and barriers associated with riparian forest buffer establishment. Information on financial and technical assistance programs available to Virginia landowners is included.

Other Publications in this series:

Understanding the Science Behind Riparian Forest Buffers: an Overview (VCE Pub. 420-150)

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