# Riparian Buffer Zones: Functions and Recommended Widths


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**For the**

**Eightmile River Wild and Scenic Study Committee**

**April 2005**

## Table of Contents

## 1. Functions of Riparian Buffers

Riparian buffers are vital elements of watersheds, primarily due to their protection of surface and ground water quality from impacts related to human land use. These vegetated buffers are complex ecosystems that provide food and habitat for unique plant and animal species, and are essential to the mitigation and control of nonpoint source pollution. In fact, the removal of streamside vegetation, primarily for development purposes, has resulted in degraded water resources and diminished value for human consumption, recreation, and industrial use.[1]

In the Eightmile River watershed, maintenance of riparian buffers in their natural condition has been identified as one of the most effective means of protecting multiple outstanding resource values (ORVs), including water quality, hydrology, unique species and natural communities, and watershed ecosystem function.

Sedimentation increases turbidity and contributes to rapid siltation of waterbodies, negatively impacting water quality. Increased sediment loads also narrow channel widths and provide substrate for colonization of invasive aquatic plant species. Intact riparian buffers ameliorate these negative impacts by stabilizing streambanks. Roots of riparian vegetation deflect wave action and hold bank soil together. The buffer vegetation also decreases erosional impacts during flood events and prevents undercutting of streambanks.

Excess nitrogen and phosphorous from fertilizers and animal waste, as well as other pollutants originating from pesticides and herbicides, often bond to soil particles. The nutrient-loaded sediment contained in surface runoff then flows to the nearest waterbody and is deposited. This process is the primary cause of accelerated eutrophication of lakes and rivers[2]. Streamside forests function as filters, transformers, and sinks for harmful nutrients and pollutants[3]. Buffer plants slow sediment-laden runoff and depending upon their width and vegetational complexity, may deposit or absorb 50 to 100% of sediments as well as the nutrients and pollutants attached to them[4]. When surface water runoff is filtered by the riparian buffer approximately 80 to 85% of phosphorous is captured[5]. Nitrogen and other pollutants can be transformed by chemical and biological soil activity into less harmful substances. In addition, riparian plants act as sinks, absorbing and storing excess water, nutrients, and pollutants that would otherwise flow into the river, reducing water quality.

One of the most important functions of riparian buffers is enhanced infiltration of surface runoff[6]. Riparian vegetation in the buffer surrounding a waterbody increases surface roughness and slows overland flows. Water is more easily absorbed and allows for groundwater recharge. These slower flows also regulate the volume of water entering rivers and streams, thereby minimizing flood events and scouring of the streambed.

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[1] Welsch 1991
[2] Jontos 2004
[3] Welsch 1991
[4] Connecticut River Joint Commission 2005
[5] Connecticut River Joint Commission 2005
[6] Dillaha et al. 1989

Many plant and animal species depend on the distinctive habitat of riparian buffers, which include elements of both terrestrial and aquatic ecosystems. Forested buffers improve habitat quality by providing shade that cools water temperatures, thereby elevating the dissolved oxygen content that is necessary for many species of fish and aquatic insects. Woody debris from shrubs and trees within the vegetated buffer provides food and cover for a multitude of aquatic species. If large enough, buffers also provide corridors essential for terrestrial wildlife movement.

Vegetated buffers may serve as screens along waterways, protecting the privacy of riverfront landowners and blocking views of any unsightly development. Hiking and camping opportunities are also facilitated by forested buffers, which if large enough, allow outdoor enthusiasts to enjoy the proximity of the water. The diversity of plant species provides visual interest and increases aesthetic appeal.

## 2. Recommended buffer widths

The width of a buffer depends greatly on what resource you are trying to protect. Scientific studies have shown that efficient buffer widths range from 10 feet for bank stabilization and stream shading, to over 300 feet for wildlife habitat. Furthermore, the necessary width for an individual site may be less or more than the average recommendations, depending on soil type, slope, land use and other factors. The ranges cited below come from four literature reviews by The U.S. Army Corps of Engineers New England Division, the University of Georgia's Institute of Ecology, the U.S. Army Engineer Research and Development Center, and researchers from the UK Forestry Commission.[7] Results from studies done in New England fall within the ranges cited below, and no evidence was found in the literature to suggest that buffers should be, on average, either wider or narrower.

### a. Erosion control

Erodibility of soil type is a key factor when assessing adequate buffer widths. Widths for effective sediment removal vary from only a few feet in relatively well drained flat areas to as much as several hundred feet in steeper areas with more impermeable soils. In order to prevent most erosion, vegetated buffers of 30 feet to 98 feet have been shown to be effective.

### b. Water quality

*Nutrients* - Nitrogen and phosphorous can be retained in buffers that range from 16 to 164 feet. The wider buffers will be able to provide longer-term storage. Nitrogen is more effectively removed than phosphorous. In 1995, a study conducted in Maine found that the effectiveness of buffers at removing phosphorous is variable but in most cases, a 49-foot natural, undisturbed buffer was effective at removing a majority of the nutrient from surface runoff. However, the U.S. Army Corps of Engineers concluded in their 1991 study that there was insufficient evidence

[7] U.S. Army Corps of Engineers 1991, Wenger 1999, Fischer and Fischenich 2000, Broadmeadow and Nisbet 2004, respectively.

to determine a necessary buffer width for phosphorous retention. It is important, therefore, to combine buffer zones with strategies to reduce phosphorous at its source.

*Pesticides* – Buffer widths for pesticide removal range from 49 feet to 328 feet. Pesticides that are applied manually require less of a buffer area than aerially-sprayed pesticides.

*Biocontaminants* – Buffer widths for biocontaminants, such as fecal coliform, were not reviewed in this study. The University of Georgia found that, in general, buffers should be 30 ft. or greater. However, buffers may not be able to adequately filter biocontaminants and it is also important to reduce these pollutants at the source.

### c. Aquatic habitat

*Wildlife* – The minimum width of riparian buffers to protect aquatic wildlife, including trout and invertebrates, range from 33 feet to 164 feet.

*Litter and debris input* – Recommendations for buffer widths to provide an adequate amount of debris for stream habitat range from 10 feet to 328 feet, although most fall within 50 feet to 100 feet.

*Stream temperature*. Adequate shading can be provided by a 30-foot buffer, but buffers may need to be up to 230 feet to completely control stream temperature. The amount of shade required is related to the size of the channel. The type of vegetation in the buffer regulates the amount of sunlight reaching the stream channel. Generally, a buffer that maintains 50% of direct sunlight and the rest in dapple shade is considered preferable[8]

### d. Terrestrial habitat

The Eightmile River watershed contains a large number of roadless, undeveloped forest blocks and is more than 80% forested in total. Furthermore, the riparian corridor within 300 ft. of the river and its tributaries has remained mostly intact, supporting a high level of biodiversity as well as protecting water quality. The Eightmile River is host to a number of important species, including native brook trout, freshwater mussels, blue back herring, bobcats, great horned owls and cerulean warblers.

The habitat requirements for birds, mammals, reptiles, amphibians and fish vary widely, and the necessary buffer width to protect each species varies widely as well. While trout and salmon can benefit greatly from the shading, habitat, food, and water quality protection that a 150-foot buffer provides, mammals such as the red fox and the bobcat require riparian corridors of approximately 330 feet. Furthermore, birds such as the cerulean warbler, which requires large areas of forest, may need a buffer that is much greater than 330 ft.[9] For this reason, we do not believe that it is feasible to capture all of the habitat needs of all species with a uniform buffer. More careful targeting of potential riparian habitat, work with landowners to create conservation

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[8] Broadmeadow and Nisbet 2004
[9] Chase et al. 1995

easements, as well as the creation of protected areas by the town will aid in more specific approaches to habitat preservation for these species.

For a more detailed look at the range of recommended buffer widths, see Appendix 1.

## 3. Factors influencing buffer width

There are many factors that influence the effectiveness buffers. These include slope, rainfall, the rate at which water can be absorbed into the soil, type of vegetation in the buffer, the amount of impervious surfaces, and other characteristics specific to the site.

### a. Slope

As slope increases, the speed at which water flows over and through the buffer increases. Therefore, the steeper the land within the buffer, the wider it needs to be to have time to slow the flow of water and absorb the pollutants and sediments within it. Many researchers suggest that especially steep slopes serve little value as a buffer, and recommend excluding areas of steep slope when calculating buffer width. The definition of "steep" varies from over 10% to over 40% slope[10].

### b. Soil type

The type of soil affects how quickly water can be absorbed. Soils that are high in clay are less permeable and may have greater runoff. On the other hand, soils that are largely made up of sand may drain water so rapidly into the groundwater that roots are not able to effectively trap pollutants. Furthermore, soils that are moister and more acidic have a better capacity to take up nitrogen from the soil and release it to the atmosphere (through denitrification).

### c. Vegetation mix

Structurally diverse riparian buffers, i.e. those that contain a mix of trees, shrubs and grasses, are much more effective at capturing a wide range of pollutants than a riparian buffer that is solely trees or grass. Removal efficiencies range from 61% of the nitrate, 72% of the total phosphorous and 44% of the orthophosphates from grass buffers to 92% of the nitrate 93% of the total phosphorous and 85% of the orthophosphates from combined grass and woody buffers. [11]

[10] Wenger 1999
[11] Jontos 2004

**Table 1:** Estimated reduction of nutrient loads from implementation of riparian buffers[12]

| Buffer Type | Nitrogen | Phosphorus | Sediment |
|---|---|---|---|
| Forested | 48-74% | 36-70% | 70-90% |
| Vegetated Filter Strips | 4-70% | 24-85% | 53-97% |
| Forested and Vegetated Filter Strips | 75-95% | 73-79% | 92-96% |

**Source**: Delaware Department of Natural Resources and Environmental Control

Generally, the grass filter strip works best for sediment removal, while the forested buffer is better for nitrate removal from subsurface flows[13]. Grasses have a shallower and denser root mat that is more effective in slowing runoff and trapping sediments from the surface flow. Trees have a deeper root system that can trap and uptake nutrients from the groundwater, stabilize banks, and regulate the flow of water to the stream.

Forests provide certain functions that grasses cannot. Trees shade the river and provide an input of leaf litter and branches that are necessary for many aquatic species. In addition, a forested buffer provides important habitat for terrestrial wildlife. Native plants species are preferred to ornamentals or exotics due to the habitat advantage they provide for wildlife. Old trees are especially valuable for providing inputs of coarse woody debris.

The most effective riparian buffers should include a mix of trees, shrubs and herbaceous plants native to the region and appropriate to the environment in which they are to be planted. When planting buffers, it is best to use adjacent reference riparian buffers as the basis for selecting floral composition[14].

**Table 2**: Plant type vs. removal efficiency

| Function | Grass | Shrubs | Trees |
|---|---|---|---|
| Sediment trapping | High | Medium | Low |
| Filtration of Sediment born Nutrients, Microbe and Pesticides | High | Low | Low |
| Soluble forms of Nutrients and Pesticides | Medium | Low | Medium |
| Flood Conveyance | High | Low | Low |
| Reduce Stream Bank Erosion | Medium | High | High |

Source: Jontos 2004 (modified after Fisher and Fischenich 2000)

[12] (Palace, 1998; Lowrance et al., 1995; Franti, T.G., (1997); Parsons et al. (1994); Gilliam et al. (1997); Osmond et al., (2000)
[13] Triangle J. Council of Governments 1999
[14] Jontos 2004

## 4. Buffer types

### a. Variable Width

Several models have been created to consider individual site factors in determining buffer width. These range from the complex to the relatively simple. The more complex models take into account multiple factors, such as slope, erodibility and infiltration rates[15]. Examples of such models include:

Brown et al. (1987):

*Buffer width = (average slope/erodibility factor)*$^{1/2}$

Cook College Department of Environmental Resources:

*Buffer width = 2.5 (time of travel of overland flow)*(slope)*$^{0.5}$

More simple models only take into account slope. A common formula is to set a fixed buffer width and apply 2 feet per percent slope. Many of these models recommend *not* including impervious surfaces or areas of steep slope in the buffer width (**Figure 1**). Cook College recommends excluding anything greater than 15% slope, while Wenger (1999) recommends excluding all slopes over 25%.

### b. Fixed Width

A fixed buffer width is the easiest to administer. However, care must be taken to select the appropriate width for the resources you are targeting. Studies unanimously support the conclusion that buffer efficiency at filtering out pollutants increases with width. However, this does not increase infinitely, and the goal is to find the most efficient width. For example, a study in the Mid-Atlantic[16] found that 90% of sediments were removed by a 62 ft. riparian buffer, but only 94% were removed by more than doubling the buffer width to 164 ft

If a fixed buffer width is chosen, it should be on the conservative side to provide leeway for slope and soil type. Data for the Eightmile River watershed show that significant areas of the land bordering the river have slopes that are above 15%. Therefore, we believe it is necessary to make a fixed buffer width wider than the average minimum recommendation of 100 ft.

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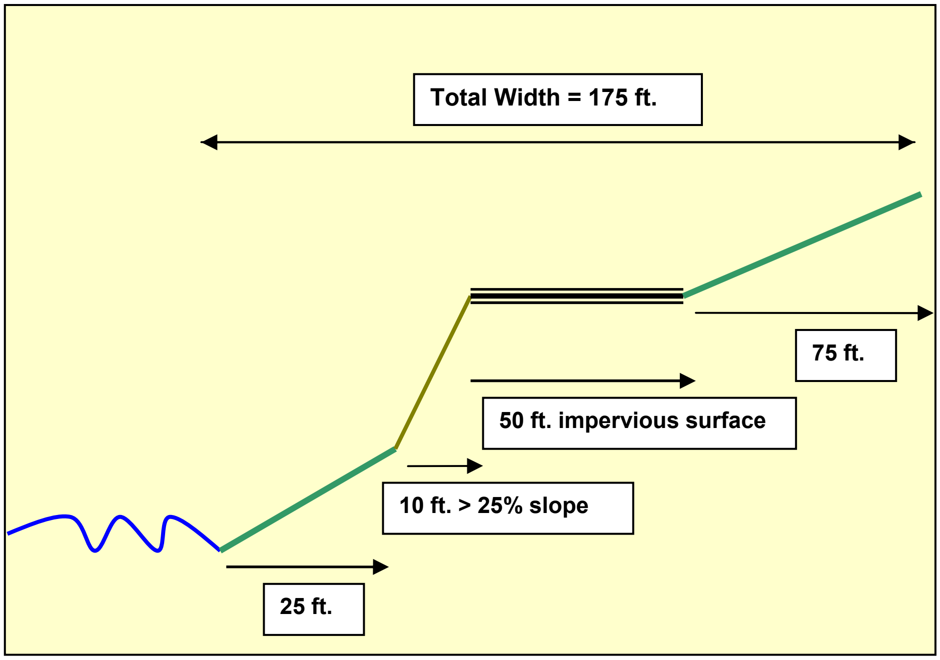
[15] Described in the US Army Corps of Engineers (1991) literature review.
[16] Peterjohn and Corell 1994.

**Fig.1**: Variable buffer width adjusted from 100 feet to 175 feet to account for effects of slope and impervious surface.




### c. Three Zone

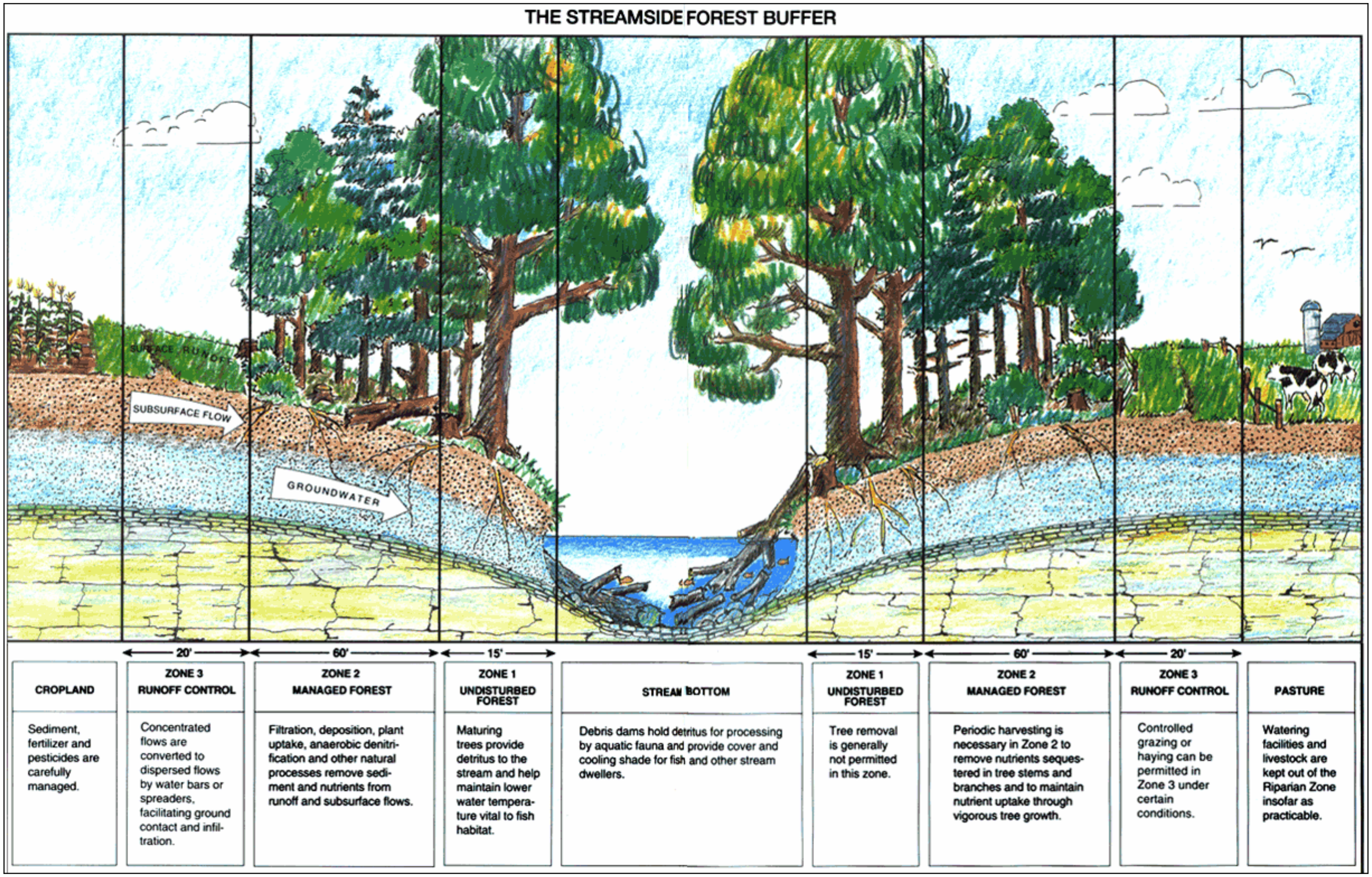
The Three Zone system was originally developed as part of an initiative to protect the Chesapeake Bay. The combination of vegetation types (trees, grass and shrubs) helps maximize the efficiency and diversity of benefits that the buffer provides (Figure 2).

<u>Zone 1</u>
*Minimum Width*: 15 ft.
*Composition*: Native trees and shrubs
*Function*: Bank stabilization, habitat, shade, flood prevention
*Management*: None allowed except bank stabilization and removal of problem vegetation.

<u>Zone 2</u>
*Minimum Width*: 60 ft.
*Composition*: Native trees and shrubs.
*Function*: Removal of nutrient, sediments and pollutants from surface and groundwater, habitat
*Management*: Some removal of trees to maintain vigorous growth.

<u>Zone 3</u>
*Minimum Width*: 30 ft.
*Composition*: Grasses and herbaceous plants
*Function*: Slow surface runoff, trap sediments and pesticides
*Management*: Mowing

Fig. 2: **Three-Zone System**




**Source**: Welsch 1991. Riparian Forest Buffers: Function and Design For Protection and Enhancement of Water Resources.

## 5. What order streams to protect

Buffers are most effective when they are contiguous. Guidelines for buffer widths recommend that long, continuous buffer strips should often be a higher priority than fragmented strips of greater width.[17] Small gaps in vegetation along the bank can channelize runoff into the river and effectively negate the effect of surrounding buffers. For this reason, landowners who currently have lawns that run to the edge of the river should be encouraged to replant trees and shrubs along the bank. In addition, footpaths cleared for river access should be winding, rather than straight, and as narrow as possible to minimize sedimentation.

Failure to extend protection to the smaller headwater streams in the river basin also ignores important sources of sedimentation and pollution. To preserve water quality in the Eightmile River, it is essential to protect all of its tributaries. In fact, smaller order streams often account for the greatest miles of watercourse in a basin. Buffering low order streams (1$^{st}$, 2$^{nd}$ and 3$^{rd}$) has greater positive influence on water quality than wider buffers on portions of larger order streams already carrying polluted water. While it may be politically infeasible to set wide buffer zones around intermittent and ephemeral streams, this omission is not justified by the science. A University of Georgia study of riparian buffers warns, "Governments that do not apply buffers to certain classes of streams should be aware that such exemptions reduce benefits substantially."[18] A review of buffers by the U.S. Army also notes that "even the best buffer strips along larger rivers and streams cannot significantly improve water that has been degraded by improper buffer practices higher in the watershed".[19]

Smaller headwater streams have the greatest area of land-water interaction, and have the greatest potential to accept and transport sediment. Ephemeral streams, which only exist during periods of high rain, can serve as important sources of sediment and pollutants to the river. It is important that they are maintained in a vegetated condition in order to help trap and slow the flow of pollutants. Furthermore, removing riparian vegetation from the banks of small, heavily shaded streams will have a much greater impact on stream temperature and aquatic habitat throughout the watershed than removing vegetation from larger rivers, where only a fraction of the water is shaded. Rather than ignoring these streams completely, a compromise would be to create a smaller setback. Clinnick et al (1985) advocate a minimum of a 20 m wide buffer for ephemeral streams, and where that is not possible, at least leaving the banks vegetated[20].

[17] Fisher and Fischenich 2000
[18] Wenger 1999
[19] Fisher and Fishenich 2000
[20] Wenger 1999

## Appendix 1–Summary of Effective Buffer Widths from Literature Review

| | Effective Width of Buffer (in feet) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Author** | **Aquatic Wildlife** | **Terrestrial Wildlife** | **Stream Temperature** | **Litter/Debris input** | **Nutrient Retention** | **Sediment Control** | **Bank Stabilization** | **Pesticide Retention** |
| Wenger 1999 | | 220-574 ft. | 33 – 98 ft. | 50 ft. | 50 – 100 ft. | 82 – 328 ft. | – | > 49 ft. |
| Army Corps 1991 | 98 ft. | 30 – 656 ft. | 33 – 66 ft. | 66-102 ft. | 52 – 164 ft. | 33 – 148 ft. | 49 – 98 ft. | 49 – 328 ft. |
| Fisher and Fischenich 2000 | > 98 ft. | 98-1,640 ft. | – | 10 – 33 ft. | 16.4-98 ft. | 30-200 ft. | 30 -66 ft. | – |
| Broadmeadow and Nisbet 2004 | 33 –164 ft. | – | 49 – 230 ft. | 82 – 328 ft. | 16.4-98 ft. | 49 – 213 ft. | – | – |

## Appendix 2 - General Recommended Widths of Buffer Zones

Source: Jontos 2004 (modified after Fisher and Fischenich 2000)

| *Function* | | **Recommended Width** |
|---|---|---|
| Water Quality Protection | Buffers, especially dense grassy or herbaceous buffers on gradual slopes, intercept overland runoff, trap sediments, remove pollutants, and promote ground water recharge. For low to moderate slopes, most filtering occurs within the first 10 m, but greater widths are necessary for steeper slopes, buffers comprised of mainly shrubs and trees, where soils have low permeability, or where NPS loads are particularly high. | 5 to 30 m |
| Stream Stabilization | Buffers, particularly diverse stands of shrubs and trees, provide food and shelter for a wide variety of riparian and aquatic wildlife | 10 to 20 m |
| Riparian Habitat | Riparian vegetation moderates soil moisture conditions in stream banks, and roots provide tensile strength to the soil matrix, enhancing bank stability. Good erosion control may only require that the width of the bank be protected, unless there is active bank erosion, which will require a wider buffer. Excessive bank erosion may require additional bioengineering techniques. | 30 to 500 m + |
| Flood Attenuation | Riparian buffers promote floodplain storage due to backwater effects, they intercept overland flow and increase travel time, resulting in reduced flood peaks. | 20 to 150 m |
| Detrital Input | Leaves, twigs and branches that fall from riparian forest canopies into the stream are an important source of nutrients and habitat. | 3 to 10 m |

## Appendix 3

References


Broadmeadow, S. and Nisbet, T.R. 2004. The effects of riparian forest management on the freshwater environment: a literature review of best management practice. Hydrology and Earth System Sciences, 8(3), 286-305.

Chase, V., Deming, L., and Latawiec, F. 1995. Buffers for wetlands and surface waters: a guidebook for New Hampshire municipalities. Audubon Society of New Hampshire.

Connecticut River Joint Commission. 2005. Introduction to riparian buffers. *From:* Riparian Buffers for the Connecticut River Valley, no.1. Available online at http://www.crjc.org/riparianbuffers.htm. Last accessed April 27, 2005.

Dillaha, T.A., J.H. Sherrard, and D. Lee. 1989. Long-term effectiveness of vegetative filter strips. Water Environ. Soc. 1:419-421.

Fischer, R.A. and Fischenich, J.C. 2000. Design recommendations for riparian corridors and vegetated buffer strips. U.S. Army Engineer Research and Development Center, Environmental Laboratory. Vicksburg, MS.

Jontos, R. 2004. Vegetative buffers for water quality protection: an introduction and guidance document. Connecticut Association of Wetland Scientists White Paper on Vegetative Buffers. Draft version 1.0. 22pp.

Krumine, M. 2004. Riparian buffers de-mystified! Tributary Times, 3(5). Delaware Department of Natural Resources and Environmental Control, Division of Water Resources. http://www.dnrec.state.de.us/water2000/Sections/Watershed/ws/trib_times_current.htm

Triangle J. Council of Governments. 1999. An introduction to riparian buffers. TJCOG Technical Memo: Riparian Buffer Series, No.1. January 1999.

U.S. Army Corps of Engineers. 1991. Buffer strips for riparian zone management. Waltham, MA.

Welsch, D.J. 1991. Riparian forest buffers: function and design for protection and enhancement of water resources. USDA Forest Service, Northeastern Area, Radnor, PA. NA-PR-07-91.

Wenger, S. 1999. A review of the scientific literature of riparian buffer width, extent and vegetation. Institute of Ecology, University of Georgia. Athens, GA

## Appendix 4 - Web Resources


Chesapeake Bay Committee. Cheasapeake Bay Riparian Handbook: A guide for establishing and maintaining riparian forest buffers. http://www.chesapeakebay.net/pubs/subcommittee/nsc/forest/handbook.htm

Connecticut Association of Wetland Scientists. Jontos, R. 2004. Vegetative buffers for water quality protection: an introduction and guidance document. http://www.ctwetlands.org/Draft%20Buffer%20Paper%20Version%201.0.doc

Connecticut River Joint Commission. 2005. Introduction to riparian buffers. *From:* Riparian Buffers for the Connecticut River Valley, no.1. http://www.crjc.org/riparianbuffers.htm.

Environmental Defense. 2003. Riparian buffers: common sense protection of North Carolina's waters. http://www.environmentaldefense.org/documents/2758_NCbuffers.pdf

Klapproth, J.C. and Johnson, J.E. 2000. Understanding the science behind riparian forest buffers: effects on water quality. Publication Number 420-151. http://www.ext.vt.edu/pubs/forestry/420-151/420-151.html

Krumine, M. 2004. Riparian buffers de-mystified! Tributary Times, 3(5). Delaware Department of Natural Resources and Environmental Control, Division of Water Resources. http://www.dnrec.state.de.us/water2000/Sections/Watershed/ws/trib_times_current.htm

Maryland Department of Natural Resources Forest Service. Riparian forest buffers: function and design for protection and enhancement of water resources. http://www.dnr.state.md.us/forests/publications/buffers.html

National Agroforestry Center. Riparian forest buffers. http://www.unl.edu/nac/riparian.html

USDA Natural Resources Conservation Service. Buffers for conservation in New Hampshire: http://www.nh.nrcs.usda.gov/features/Buffers/what_buffers.html

Welsch, D.J. 1991. Riparian forest buffers: function and design for protection and enhancement of water resources. USDA Forest Service, NA-PR-07-91. http://www.na.fs.fed.us/spfo/pubs/n_resource/buffer/cover.htm

Wenger, S. 1999. A review of the scientific literature of riparian buffer width, extent and vegetation: http://outreach.ecology.uga.edu/tools/buffers/lit_review.pdf