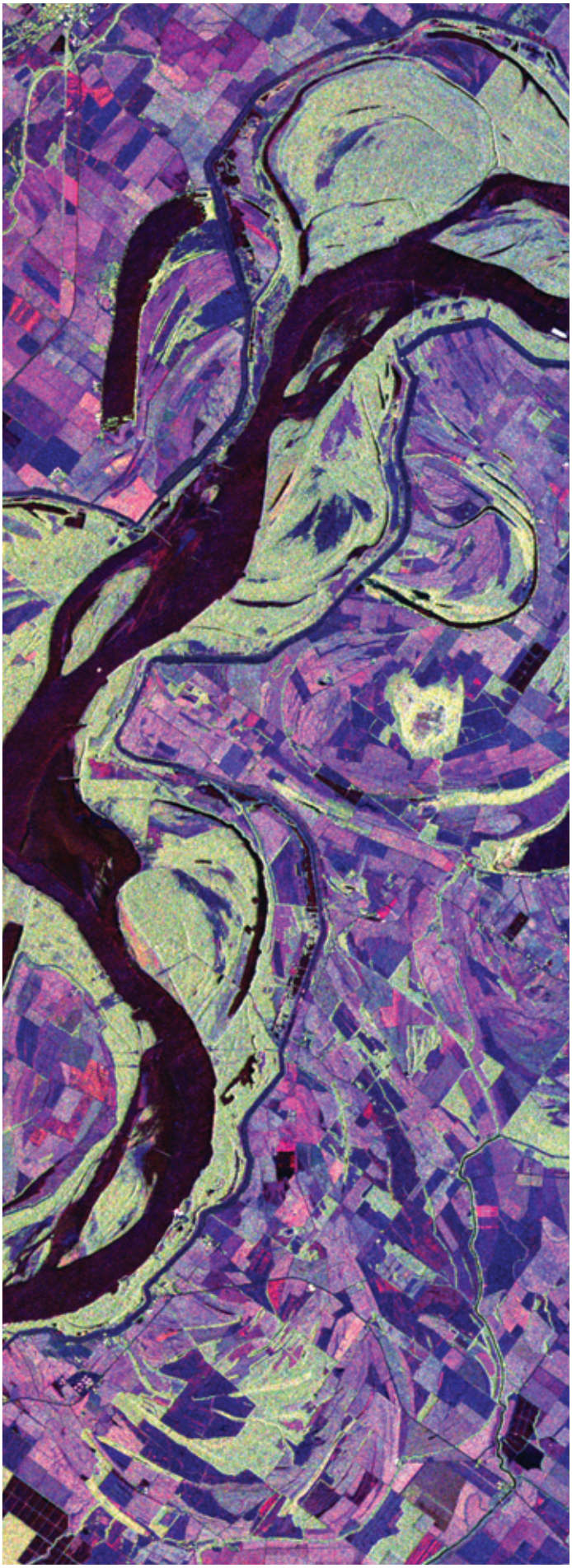

Courtesy of NASA Jet Propulsion Laboratory

Riparian Management Practices

A Summary of State Guidelines

Charles R. Blinn and Michael A. Kilgore

ABSTRACT

Individual states develop guidelines to protect and manage forest riparian resources. A review of 49 states' forest riparian guidelines revealed the primary focus is to protect the quality of water adjacent to perennial and intermittent streams and lakes. A commonly recommended riparian management zone is 50 feet wide with 50 to 75 percent crown closure (or 50–75 square feet per acre of residual basal area); however, the specific guidelines in each state vary tremendously. Although science cannot specify the management prescriptions needed to protect all riparian functions across all sites, understanding site-specific conditions is critical to effective guideline implementation.

Keywords: best management practices; water quality

Riparian forests are undoubtedly one of the most widely studied and debated components of forest ecosystems. Hundreds of articles, dozens of books, and numerous bibliographies and reviews have been written on the ecology of riparian areas and their management (e.g., Belt et al. 1992; Castelle et al. 1992; Van

Left: **This synthetic aperture radar (SAR) image, acquired during a 1994 mission of the space shuttle *Endeavor,* shows the Mississippi River along three state lines: Louisiana and Arkansas lie above the river and Mississippi is below it. The town in the upper left corner is Eudora, Arkansas, and the green regions bordering the river are undeveloped forested areas.**

Courtesy of Minnesota Department of Natural Resources

This aerial photo shows two timber harvests, one on each side of a stream, with a riparian buffer strip between each harvest site and the stream. The location is Lake County in northeastern Minnesota.

Deventer 1992; Correll 1999; Wenger 1999; Castelle and Johnson 2000; Koehler and Thomas 2000; Verry et al. 2000; Wigington and Beschta 2000). Defined as the aquatic ecosystem as well as the boundary between aquatic and terrestrial ecosystems, the moist and often wet soils and high water tables associated with riparian areas make them one of the most important and diverse parts of a forest ecosystem. These systems vary considerably in their size, vegetation, species abundance, and diversity. In addition to their ecological importance, they provide a range of functions with economic and social value.

As knowledge of riparian forests expands, so too have concerns about managing within these areas (Verry and Dolloff 2000). Today, resource managers and timber harvesters are being challenged to minimize adverse impacts to riparian systems when operating near water bodies. They rely on best management practices (BMP) to provide guidance for operating within these areas. States initially developed forest management BMPs in response to the federal Clean Water Act of 1972. The primary focus of those BMPs was to reduce nonpoint source pollution associated with timber harvesting and forest management activities.

By 1996, 47 states had programs to promote forestry BMPs (National Association of State Foresters 1996). These BMPs recognize the importance of establishing buffer zones, otherwise known as riparian management zones (RMZ), riparian management areas, streamside (or special) management zones (SMZ), stream protection zones, and buffer strips. An important purpose of those buffer areas is to protect the functions and values of the water body and its associated riparian area from the impact of site-level activities. Therefore, the guidelines provide recommendations for modifying management activities.

Although BMPs incorporate the best available science, the base of knowledge is not extensive in some areas of the country and for some practices. Therefore, guideline developers often must rely on knowledge and approaches from another region of the country or attempt to provide commonsense recommendations for some issues.

National Review

In February 2000, we contacted state foresters in all states and asked them to provide us with a copy of state BMPs, guidelines, or forest practice regulations regarding timber harvesting within riparian areas. We did not review the extent to which federal laws, local regulations, or zoning ordinances affect timber harvesting activities within riparian areas. When it was not possible to obtain a copy of a state's guidebook, we obtained information from a website maintained by the Southern Forestry Extension Service (www.usabmp.net). This site provides links to several state BMP guidebooks.

We reviewed the guidebooks and online information to identify the riparian guidelines. Appropriate information from each guidebook was initially summarized into a table and key trends were identified. When we compiled the tabular summary, we made every attempt to only include information from the particular water bodies that each state defined as being a part of their RMZ, SMZ, stream protection zone, or buffer strip guidelines. If a guidebook contained information

about water bodies that were not included within their management zone definition, we excluded those additional water bodies from the summary.

Focus of Guidelines

We reviewed forest management guidelines used in 49 states (guidelines for Arizona were not available). Of the 38 guidebooks that provided a publication date, seven were published in 2000, 14 during 1997–99, 11 during 1993–96, and six prior to 1993. As evidence that the guidelines process is evolutionary and that revisions are based on the results of monitoring and accumulated knowledge (Norman 1996), several states are in the second or third edition of their guidebook. A few indicated they are currently in the process of revising their guidelines. Only the most recent published riparian guidelines were reviewed.

The focus of riparian guidelines is often on water quality protection. Water quality issues cited include sediments, nutrients, pesticides, fuels and lubricants, organic matter, and thermal impacts. Some states noted consideration of additional riparian functions and values beyond water quality. For example, Minnesota's riparian guidelines reference a variety of functions and values such as wildlife habitat, biological diversity, and aesthetics.

State riparian guidelines address a variety of different water bodies, the most common of which are noted in *table 1.* Perennial streams were the most commonly identified water body, found in all 49 state guidebooks reviewed. For four of the states indicating they have guidelines for "streams," it was assumed that those are perennial streams as no definition of "streams" was found in their guidebook. Although some states have labeled their guidelines as "streamside management zone" practices, their guidelines also may address nonstream water bodies such as wetlands, lakes, and ponds. Forty state riparian guidelines recognize intermittent streams, whereas only slightly more than half acknowledge lakes. Other water bodies referenced by at least 10 states include domestic water supplies (17 states), wetlands (11 states), and ponds (11 states).

In three states, forest riparian guidelines vary depending on the geographic location within the state. A few states with regulatory programs have both required guidelines and additional recommendations that go beyond the requirements. No states limit the extent or length of a harvest area along all water bodies or the size of the harvest activity.

Table 1. Types of water bodies addressed by state forest riparian guidelines.

Type of water body	Number of states with guidelines
Perennial streams	49
Intermittent streams	40
Lakes	27
Domestic water supplies	17
Wetlands	11
Ponds	11

Guideline Components

The guidelines generally contain three basic components: a minimum RMZ width; minimum amount of residual trees remaining following timber harvesting activities (residual tree recommendations); and additional guidelines addressing a variety of management practices within the management zone (e.g., management of nontree vegetation). Summary information from each of those three components is presented below, focusing on perennial streams, intermittent streams, and lakes.

RMZ width recommendations. Crow et al. (2000) reported that the minimum RMZ width required to protect the riparian area depends on factors such as groundwater and flood hydrology, critical species habitat, the structural characteristics of the riparian forest, the gradients controlled by physiographic features such as slope, and the degree of contrast between the riparian area and the adjacent landscape. Because each riparian area is unique and there are too many variables that need to

Table 2. Regional summary of minimum riparian management zone (RMZ) width for perennial and intermittent streams and lakes: number of states and (percent of region).

	Perennial streams			Intermittent streams			Lakes		
Minimum RMZ width (feet)	North 20 states	South 13 states	West 16 states	North 14 states	South 12 states	West 14 states	North 10 states	South 5 states	West 12 states
25	4 (20)	2 (16)	0 (0)	4 (29)	4 (33)	0 (0)	2 (20)	1 (20)	0 (0)
26–50	9 (45)	10 (76)	5 (31)	6 (43)	7 (58)	4 (28)	4 (40)	4 (80)	3 (25)
51–75	1 (5)	0 (0)	4 (25)	0 (0)	0 (0)	4 (28)	0 (0)	0 (0)	5 (42)
76–100	4 (20)	0 (0)	2 (13)	3 (21)	0 (0)	2 (14)	3 (30)	0 (0)	1 (8)
101–130	1 (5)	0 (0)	2 (13)	1 (7)	0 (0)	2 (14)	1 (10)	0 (0)	1 (8)
200	0 (0)	0 (0)	1 (6)	0 (0)	0 (0)	1 (7)	0 (0)	0 (0)	1 (8)
Not specified	1 (5)	0 (0)	1 (13)	0 (0)	0 (0)	1 (7)	0 (0)	0 (0)	1 (8)
Site specific	0 (0)	1 (8)	0 (0)	0 (0)	1 (8)	0 (0)	0 (0)	0 (0)	0 (0)

NOTES: *Summary includes states that have guidelines for "streams" and "perennial streams" in* table 1. *Values for some states represent an average across two or more classifications. Each water body type is based on size or other criteria within each state's guidebook. Percentages for some columns may not equal 100 due to rounding.*
North: *Connecticut, Delaware, Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, West Virginia, Wisconsin.*
South: *Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia.*
West: *Alaska, California, Colorado, Hawaii, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, Wyoming.*

Table 3. Regional summary of minimum riparian management zone (RMZ) residual tree recommendations for perennial streams and lakes: number of states and (percent of region).

Minimum residual tree recommendation	Perennial streams			Lakes		
	North 20 states	South 13 states	West 16 states	North 10 states	South 5 states	West 12 states
25–80 ft^2/acre of basal area	1 (5)	0 (0)	0 (0)	1 (10)	0 (0)	0 (0)
50 percent of crown closure, 50 percent of original canopy, 50 percent of original basal area, or 50 ft^2/acre of basal area	3 (15)	9 (69)	2 (13)	1 (10)	3 (60)	2 (17)
60 percent of crown closure or 60 ft^2/acre of basal area	4 (20)	0 (0)	0 (0)	3 (30)	0 (0)	0 (0)
70 percent of crown closure	1 (5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
75 percent of preharvest shade on stream	0 (0)	1 (8)	2 (13)	0 (0)	1 (20)	1 (8)
40 live conifer trees per 1,000 feet along large streams and 30 live conifers per 1,000 feet along medium streams	0 (0)	0 (0)	1 (6)	0 (0)	0 (0)	0 (0)
250 ft^2/acre of basal area at age 140	0 (0)	0 (0)	1 (6)	0 (0)	0 (0)	1 (8)
Sufficient number of trees to maintain shading	3 (15)	0 (0)	1 (6)	2 (20)	0 (0)	0 (0)
Avoid clearcutting	0 (0)	0 (0)	1 (6)	0 (0)	0 (0)	1 (8)
Landowner objectives	0 (0)	1 (8)	0 (0)	0 (0)	0 (0)	0 (0)
No harvesting	0 (0)	0 (0)	2 (13)	0 (0)	0 (0)	1 (8)
Not specified	8 (40)	2 (15)	6 (38)	3 (30)	1 (20)	6 (50)

NOTES: *Summary includes states that have guidelines for streams and perennial streams in* table 1. *Values for some states represent an average across two or more classifications. Each water body type is based on size or other criteria within each state's guidebook. Percentages for some columns may not equal 100 due to rounding.*
North: *Connecticut, Delaware, Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, West Virginia, Wisconsin.*
South: *Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia.*
West: *Alaska, California, Colorado, Hawaii, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, Wyoming.*

be considered, little scientific data exists to support the use of specific buffer widths across all sites (Crow et al. 2000; Palik et al. 2000; Todd 2000). Several studies report that most of the potential contributions of riparian vegetation to the ecological functions within a stream are realized within the first 15 to 100 feet from the stream bank. RMZ widths in that range typically provide at least 50 percent of potential effectiveness and often 75 percent or greater effectiveness at protecting various stream functions (Castelle and Johnson 2000). As some studies compared the effectiveness of different buffer widths where no harvesting was performed within the RMZ, the actual effectiveness of the management zone might be different when harvesting does occur.

The width of an RMZ can be either: (1) a fixed width or standard width that may vary based on slope or water body type; or (2) a variable width that is based on specific site conditions such as composition, age, and condition of the vegetation, site geomorphology, watershed-level issues, and animal and plant species present on the site (Belt et al. 1992; Castelle and Johnson 2000; Phillips et al. 2000). While fixed-width, one-size-fits-all approaches are easier to apply, variable-width RMZs offer greater flexibility in landscape-level protection (O'Laughlin and Belt 1995). Ilhardt et al. (2000) describe a functional approach to defining riparian areas that uses the variable-width approach. Under that approach, the extent of the riparian area is defined on the ground by the strength of ecosystem functions.

Our analysis of state RMZ guidelines found the fixed-width approach is most commonly applied to define RMZ width. A 50-foot minimum RMZ width from either the edge of the water body or the ordinary high-water mark is frequently recommended for perennial streams, intermittent streams, and lakes *(table 2).* Recommended widths for intermittent streams are generally lower than for perennial streams or lakes. Recommended RMZ widths tend to be highest in the West and lowest in the South. Although these regions vary in forest vegetation, topography, and the proportion of cold-water streams, part of the differences in RMZ width may be due to the processes used to develop state guidelines.

Approximately 75 percent of the states publish both minimum, base-level, fixed-width recommendations and additional values that increase the width depending on water body size or slope or by incorporating slope effects with water body size or soil erodibility. Some states also note that, despite their fixed-width values, the actual RMZ width should be determined during an onsite evaluation that considers factors such as size and type of water body, topography, soils, vegetative cover, and special site conditions. Landowner objectives are infrequently cited as being a modifier of RMZ width recommendations.

States vary widely in the number of slope categories that can modify the base-level RMZ width for a water body, from two to 11 categories, with three or four categories being most common. Seven of the 21 states that use slope percentage to modify the base-level RMZ width adjacent to a perennial stream establish wider guidelines once the slope exceeds 10 percent. The other two-thirds are divided equally between states that identify breakpoints below 10 percent (0–9 percent slope) and

above (14–35 percent slope).

States have defined either two or three categories of water body size or soil erodibility to modify the base-level RMZ width. For most states whose guidelines increase the recommended RMZ width with stream width, a perennial stream width of 19 feet is the most common breakpoint. This breakpoint ranges from 2 to 25 feet. None of the states increase the width of the management zone with decreasing stream width. The classifications (1) "slightly erodible" and "erodible," (2) "slightly erodible" and "severely erodible," or (3) "low," "moderate," and "high" erodibility are used by three states to separate the additional effects of soil on RMZ width.

Three states divide the fixed-width RMZ into two or three different strips or zones where the one closest to the water's edge has the most management restrictions (e.g., fewer trees can be removed, less equipment traffic is allowed) and the outer strip or zone the least restrictions. The width of the outer zone is extended with increasing slope and soil erodibility. Other states attempt to achieve something similar by recommending that no trees are to be harvested from the bed or banks if doing so will destabilize the soil, degrade water quality, or reduce shading of the water body.

Residual tree recommendations. The amount of residual trees left in the RMZ after harvest is also an important component of timber harvesting guidelines. State guidebooks identify a variety of methods to define residual trees. Basal area (either percent of original basal area or amount of residual basal area) and crown spacing (either percent of original canopy or percent of crown closure within the residual stand) are the methods used most frequently. Other methods include retaining a specified percent of preharvest shade on the water body, retaining a specified percent of original live trees, and retaining a sufficient number of trees to maintain shading of the water body. Many states recommend using uneven-aged management within the RMZ.

Minimum residual basal area values included in state riparian guidelines are generally in the range of 50 to 75 square feet per acre or 50 to 75 percent crown closure for perennial streams and lakes *(table 3).* Several states do not specify a minimum residual tree recommendation, leaving that determination up to the on-the-ground manager. Guidelines for perennial streams and lakes in the North and West are more likely not to specify residual tree recommendations. Nine states indicate that residual trees should be evenly or well-distributed within the management zone. Several states indicate the importance of leaving more trees closer to the water's edge. This approach, which is more commonly recommended for perennial streams and lakes, is generally accomplished by establishing a no-harvest or partial-harvest-only zone within a specified distance of the water's edge.

Table 4. Regional summary of minimum riparian management zone (RMZ) residual tree recommendations for intermittent streams: number of states and (percent of region).

Minimum residual tree recommendation	North 14 states	South 12 states	West 14 states
0 percent of overstory trees	0 (0)	1 (8)	0 (0)
25 ft^2/acre of basal area or 25 percent of crown closure	0 (0)	1 (8)	0 (0)
25–80 ft^2/acre of basal area	1 (7)	0 (0)	0 (0)
50 percent of crown closure, 50 percent of original canopy, 50 percent of original basal area, or 50 ft^2/acre of basal area	1 (7)	3 (25)	2 (14)
60 percent of crown closure or 60 ft^2/acre of basal area	4 (29)	0 (0)	0 (0)
70 percent of crown closure	1 (7)	0 (0)	0 (0)
75 percent of pre-harvest shade on stream or original forest	0 (0)	1 (8)	1 (7)
30 live conifer trees per 1,000 feet along large streams and 10 live conifers per 1,000 feet along medium streams	0 (0)	0 (0)	1 (7)
250 ft^2/acre of basal area at age 140	0 (0)	0 (0)	1 (7)
Sufficient number of trees to maintain shading	2 (14)	0 (0)	0 (0)
Avoid clearcutting	0 (0)	0 (0)	1 (7)
No harvesting	0 (0)	0 (0)	2 (14)
Not specified	5 (36)	6 (50)	6 (43)

NOTES: Values for some states represent an average across two or more classifications of intermittent streams based on size or other criteria within each state. Percentages for some columns may not equal 100 due to rounding. For streams that do not have fish use, conifers must be at least 11 inches diameter at breast height (dbh) for large streams and 8 inches dbh for medium streams. Many states note that although minimum residual tree recommendations are not identified, it is important to retain other vegetation or ground cover to protect the forest floor and the stream bank in a manner that will maintain water quality.
North: *Connecticut, Delaware, Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, West Virginia, Wisconsin.*
South: *Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia.*
West: *Alaska, California, Colorado, Hawaii, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, Wyoming.*

Residual tree recommendations for intermittent streams are either the same or lower than those for perennial streams or lakes *(table 4).* As with RMZ width, residual tree recommendations tend to be highest in the West and lowest in the South. Again, regional differences may be attributed to both the ecological and physical setting and the processes by which individual state guidelines were developed.

Additional RMZ recommendations. Most states specify one or more additional guidelines that are designed to modify operations within the RMZ. While some of those recommendations relate to management of the nontree vegetation, other factors are also addressed. Those guidelines may be found within the section on riparian

Other Recommendations for Riparian Management Zones

This list includes some of the more frequently cited "other recommendations" for riparian management zones (RMZ) beyond width and residual vegetation recommendations. Each guideline appears in at least 10 state guidebooks. As the specific wording of each guideline varies from state to state, they are paraphrased here. Words within [brackets] are modifiers found in some guidebooks.

Planning Guidelines

- Clearly mark outside boundaries of the RMZ before operations begin.
- Maintain an adequate filter strip, which minimizes disturbance of the forest floor, exposure of mineral soil, and disturbance to other vegetation. (Some states specify a maximum amount of mineral soil exposure within a specified distance of the water's edge. Width of the filter strip is often slope dependent.)
- Minimize the number of water crossings. Locate water crossings where impacts are likely to be minimal.
- Where feasible, locate [new] roads outside of the RMZ and filter strip.
- When road construction cannot be avoided, access roads should cross stream channels and RMZs at or near a right angle.
- Where feasible, locate [new] landings and log decks, skid trails, and sawmills outside of the RMZ.
- Designate specific areas for refueling equipment, equipment storage, and equipment maintenance outside of the RMZ.
- Use cable skidders when ground skidding systems are employed.
- Avoid operating [skidding] equipment within the RMZ; operate ground-based equipment within the RMZ only when the ground is dry or frozen (to minimize rutting) or use appropriate light-on-the-land equipment.

Operational Guidelines

- Drainage structures should be used on roads and skid trails prior to their entrance into an RMZ and on approaches to water crossings to intercept and properly discharge runoff waters.
- Do not move slash into or pile slash within the RMZ.
- Remove any tops or other logging debris that are dropped into the water or channel.
- Do not harvest trees from banks, beds, or steep slopes if it will destabilize the soil, degrade water quality, or reduce shading over the water body.
- Use directional felling techniques to fell trees away from the water body, except where safety is a concern.

management zones or within other guidebook sections (e.g., roads, landings, skid trails, stream crossings).

Several additional timber harvesting recommendations are included in at least 10 guidebooks (see "Other Recommendations for Riparian Management Zones"). Fewer than 10 states have guidelines that indicate the following: (excessive) rutting within the RMZ should be avoided; management should favor long-lived, uneven-age species; the stream or stream channel should not be used as a skid trail or road; trees on the south and west banks provide the most critical shading of water; or planning should include development and management of wildlife habitat. A few states prescribe leave-tree requirements within a specified distance from the high-water mark on both sides of streams along a thousand-foot stream segment in order to provide large organic debris. Explicit consideration of the future forest, facilitating adequate regeneration, and maintaining the health of RMZ trees are not commonly addressed.

Factor Relationships

Pearson product moment correlation coefficients between RMZ width, residual tree recommendations, and slope were calculated to assess the relationship between pairs of factors. There is a relatively strong correlation between RMZ width and residual tree recommendations (0.74), indicating that states with higher RMZ widths also have higher residual tree recommendations. Correlation is weaker between RMZ width and slope (0.30) and between residual tree recommendations and slope (–0.27). Low correlation is not a surprise for those two comparisons given the relative breadth of RMZ width and residual tree recommendations as compared to the few slope breakouts identified.

Looking Beyond the Numbers

The Minnesota Forest Resources Council (2000) conducted a science-based review of its riparian and seasonal pond guidelines. A primary purpose of the review was to assess the consistency of the guidelines with current science and knowledge from a variety of disciplines (e.g., silviculture, ecology, and hydrology). Many of the points raised during the review are pertinent to other states' forest riparian guidelines (further information on many of these points can be found in Verry et al. 2000). Findings of the Council's review include:

- Small to moderate changes in hydrology within the riparian area can lead to significant changes in plant species composition. As such, maintaining the hydrology of a riparian area is the most important overall consideration. Anything that alters the hydrology (e.g., skid trails, bridges, roads, soil compaction, or rutting) changes the dynamics of the riparian zone.
- The importance of riparian functions increases with decreasing distance to the water. A commonsense rule is to be more sensitive the closer one operates to the water body.
- Science cannot specify with certainty the RMZ width and amount of residual trees needed to protect all riparian functions. The specific width of an RMZ will vary according to the type of water body, site conditions, and

specific riparian functions and values needing the most protection.

• A higher residual basal area does not automatically mean greater protection to the riparian resource. For example, a stand could have a high basal area but few trees and be less effective in protecting against sedimentation and thermal impacts than a stand with a lower basal area, lots of smaller-diameter trees, and a dense shrub component.

• Residual tree recommendations often are not consistent with the silvicultural prescription needed within the RMZ. Although residual trees may protect riparian functions in the short term, these recommendations generally lack a long-term view of the desired future riparian forest vegetation. RMZ silvicultural prescriptions should consider multiple entries, regeneration planning, stand-density regulation through thinning, and the distribution of residual vegetation to avoid overlooking the spatial and temporal scales of forest ecology and how the remaining composition and distribution affects succession.

• Because RMZ guidelines are site-based, they do not address landscape-level issues and cumulative effects. The types and intensity of land-use practices (e.g., the extent of harvest, conversion to nonforested status, development) within a landscape can have a greater influence on aquatic ecosystems than specific RMZ parameters (e.g., width, amount of residual trees).

• Scale issues of a harvest unit (i.e., length of harvest unit along a stream) are important. For example, the impact on fish populations could be significant if relatively few trees are left along a long stream reach.

Applying the Guidelines

Forest riparian guidelines need to incorporate the best available science, yet recommend economically feasible and practical timber harvesting and forest management practices. Individuals responsible for developing such guidelines need research results that are relevant to the various water bodies and site conditions found within their state. With the increasing emphasis on riparian resource protection, on-the-ground managers need additional information to help them apply RMZ guidelines to a particular setting. They also need more training to understand how to evaluate site-based conditions and resource needs so they feel comfortable modifying fixed-width recommendations or implementing variable-width approaches. Field keys that help integrate the large amount of information about riparian areas into a site-based, variable-width approach for protecting and enhancing functionality during harvesting activities, combined with field training on the application of the key, could help increase the effectiveness of on-the-ground management and riparian resource protection.

Literature Cited

BELT, G.H., J. O'LAUGHLIN, and T. MERRILL. 1992. *Design of forest riparian buffer strips for the protection of water quality: Analysis of scientific literature.* Policy Analysis Group Report No. 8. Moscow: University of Idaho, College of Forestry, Wildlife, and Range Sciences.

CASTELLE, A.J., and A.W. JOHNSON. 2000. *Riparian vegetation effectiveness.* Technical Bulletin No. 799. Research Triangle Park, NC: National Council for Air and Stream Improvement.

CASTELLE, A.J., C.C. CONOLLY, M. EMERS, E.D. METZ, S. MEYER, and M. WITTER, eds. 1992. *Wetland buffers: An annotated bibliography.* Publication No. 92-11. Olympia: Washington State Department of Ecology, Shorelands and Coastal Zone Management Program.

CORRELL, D.S. 1999. *Vegetated stream riparian zones: Their effects on stream nutrients, sediments, and toxic substances (8th ed.).* Edgewater, MD: Smithsonian Environmental Research Center. Available online at www.serc.si.edu/SERC_web_html/pub_ripzone.htm. Last accessed by authors May 2001.

CROW, T.R., M.E. BAKER, and B.V. BARNES. 2000. Diversity in riparian landscapes. In *Riparian management in forests of the continental eastern United States,* eds. E.S. Verry, J.W. Hornbeck, and C.A. Dolloff, 43–65. Boca Raton, FL: Lewis Publishers.

ILHARDT, B.L., E.S. VERRY, and B J. PALIK. 2000. Defining riparian areas. In *Riparian management in forests of the continental eastern United States,* eds. E.S. Verry, J.W. Hornbeck, and C.A. Dolloff, 23–41. Boca Raton, FL: Lewis Publishers.

KOEHLER, D.A., and A.E. THOMAS, comps. 2000. *Managing for enhancement of riparian and wetland areas of the western United States: An annotated bibliography.* General Technical Report RMRS-GTR-54. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station.

MINNESOTA FOREST RESOURCES COUNCIL. 2000. *Peer review group discussion summary.* St. Paul.

NATIONAL ASSOCIATION OF STATE FORESTERS. 1996. *State nonpoint source pollution control programs for silviculture: 1996 progress report.* Washington, DC.

NORMAN, A.J. 1996. The use of vegetative buffer strips to protect wetlands in southern Ontario. In *Wetlands: Environmental gradients, boundaries, and buffers,* eds. G. Mulamoottil, G., B.G. Warner, and E. A. McBean, 263–78. Boca Raton, FL: CRC Press.

O'LAUGHLIN, J., and G.H. BELT. 1995. Functional approaches to riparian buffer strip design. *Journal of Forestry* 93(2):29–32.

PALIK, B.J., J.C. ZASADA, and C.W. HEDMAN. 2000. Ecological principles of riparian silviculture. In *Riparian management in forests of the continental eastern United States,* eds. E.S. Verry, J.W. Hornbeck, and C.A. Dolloff, 233–54. Boca Raton, FL: Lewis Publishers.

PHILLIPS, M.J., L.W. SWIFT JR., and C.R. BLINN. 2000. Best management practices for riparian areas. In *Riparian management in forests of the continental eastern United States,* eds. E.S. Verry, J.W. Hornbeck, and C.A. Dolloff, 273–86. Boca Raton, FL: Lewis Publishers.

TODD, A.H. 2000. Making decisions about riparian buffer width. In *Riparian ecology and management in multi–land use watersheds,* eds. P.J. Wigington and R.L. Beschta, 445–50. Middleburg, VA: American Water Resources Association.

VAN DEVENTER, J.S. 1992. *A bibliography of riparian research and management: Fish, wildlife, vegetation, and hydrologic responses to livestock grazing and other land use activities.* Contribution No. 643. Moscow: University of Idaho, Idaho Riparian Cooperative.

VERRY, E.S., and C.A. DOLLOFF. 2000. The challenge of managing for healthy riparian areas. In *Riparian management in forests of the continental eastern United States,* eds. E.S. Verry, J.W. Hornbeck, and C.A. Dolloff, 1–22. Boca Raton, FL: Lewis Publishers.

VERRY, E.S., J.W. HORNBECK, and C.A. DOLLOFF, eds. 2000. *Riparian management in forests of the continental eastern United States.* Boca Raton, FL: Lewis Publishers.

WENGER, S. 1999. *A review of the scientific literature on riparian buffer width, extent and vegetation.* Athens: University of Georgia, Institute of Ecology, Office of Public Service and Outreach.

WIGINGTON, P.J., and R.L. BESCHTA, eds. 2000. *Riparian ecology and management in multi–land use watersheds.* Middleburg, VA: American Water Resources Association.

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