Chapter 2

Defining Riparian Areas

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"The riparian corridor is the heart of the drainage basin since it may be the ecosystem level component most sensitive to environmental change."

Naiman et al. 1992b

What is a riparian area? Does it include the aquatic environment or only the transition between aquatic and terrestrial environments? Does the transition include only lands with saturated or seasonally saturated soils or all land that influences or is influenced by the aquatic environment? Definitions vary with the perspective of the author and user. Typically, they center on which components of the landscape are included, which characteristics of a component, which landscape scales are considered, or which legislative mandates for water quality best management practices (BMPs).

We review the many definitions available from agencies and from several disciplines and offer a definition based on the long-term sustainability of ecologic functions in riparian areas. An ecosystem function is a collection of processes that govern the flow of energy and materials (e.g., sunlight, leaf carbon, water, sand, and nutrients). Our definition includes the water body, riparian land, and parts of upland areas that have a strong linkage to the water. This definition is not associated with a management prescription or BMP, rather, it defines a *riparian area* by the strength of the ecosystem functions associated with it. Under this definition, the boundaries of riparian areas typically are less uniform than those associated with fixed-distance prescriptions for filter strips, buffer strips, or streamside management zones (SMZs). We delineate riparian areas by examining how the ecosystem function changes with distance from the water. Finally, we offer a field key to delineate riparian areas on the ground.

Many Definitions

Many states define riparian areas to regulate land disturbance activities, to protect water quality, and to comply with the Federal Clean Water Act. "Streamside management zones," "buffer zone" or "buffer strip" and "riparian management zones," are the terms most frequently used, and minimum widths are usually specified. The riparian management zone excludes the aquatic component and delineates the land and vegetation that buffers the surface water from land disturbance. In our conclusions from the following discussion, we include the aquatic component and use the broader term--riparian area.

Agency Perspectives

A review of state BMPs in the Eastern United States revealed that, while the terminology differs, the focus is the same--water-quality protection. New Hampshire has proposed revising 1972 BMPs to address maintenance and protection of the key riparian and wetland ecological functions. Minnesota revised its water-quality BMPs in 1995 to include protection of hydrologic function in wetlands. They were revised again in 1999 to include riparian management practices, site productivity, wildlife, and the cultural aspect of forest management.

Many federal agencies define riparian areas and identify riparian-area components, however, definitions are not consistent among agencies. The USDA Forest Service defined riparian area to include the aquatic ecosystem, the riparian ecosystem and wetlands (USDA Forest Service 1994). While this broadly defines riparian areas, a "riparian ecosystem" is restricted to those areas with soil characteristics or distinctive vegetation that requires free or unbound water (thus the stream, lake, or open-water wetland is not included).

The Eastern Region (Region 9) of the Forest Service recognizes the deficiencies in this definition and supports the following functional definition:

> "Riparian areas are composed of aquatic ecosystems, riparian ecosystems and wetlands. They have three dimensions: longitudinal extending up and down streams and along the shores; lateral to the estimated boundary of land with direct land-water interactions; and vertical from below the water table to above the canopy of mature site-potential trees (Parrott et al. 1997)."

In this definition, the "aquatic ecosystem" includes the stream channel, lake, estuary beds, water, biotic communities, and the habitat features that occur therein; the "riparian ecosystem" is defined as extending away from the bank or shore to include land with direct land-water interactions, and whose areal extent is variable based on its ability to perform ecologic functions. The wetland part of the definition is consistent with other federal agencies that have adopted the USDI Fish and Wildlife Service's wetland definition and includes "those areas that are inundated or saturated by surface or groundwater at a frequency sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions (USDA Forest Service 1994)."

The Coastal Zone Management Act excludes the aquatic ecosystems and defines riparian areas as:

> "...vegetated ecosystems along a water body through which energy, materials and water pass." They further characterize riparian areas as having a high water table, subject to periodic flooding and encompassing wetlands.

The USDI Bureau of Land Management definition excludes the aquatic component and defines riparian area as:

> ". . . a form of wetland transition between permanently saturated wetlands and upland areas (USDI, 1993)."

They further state that these areas contain vegetation or physical characteristics reflecting permanent surface or subsurface water influence. The BLM definition includes land along and adjacent to, or contiguous with perennially or intermittently flowing rivers and streams, glacial potholes and the shores of lakes and reservoirs but excludes ephemeral streams or washes that do not contain hydrophytic vegetation.

The Fish and Wildlife Service recently adopted a definition to guide their mapping of riparian areas in the Western United States where mean annual evaporation exceeds mean annual precipitation. They, too, recognize that many definitions are used by government agencies and the private sector, with some based on functionality and others on land use. Their definition, which follows, was developed to ensure consistency and uniformity in identification and mapping:

> "Riparian areas are plant communities contiguous to and affected by surface and subsurface hydrologic features of perennial or intermittent lotic and lentic water bodies (rivers, streams, lakes, or drainage ways). Riparian areas have one or both of the following characteristics: (1) distinctly different vegetative species than adjacent areas, and (2) species similar to adjacent areas but exhibiting more vigorous or robust growth forms. Riparian areas are usually transitional between wetland and upland (USDI Fish and Wildlife Service 1997)."

Discipline Perspectives

The word "riparian" is drawn from the Latin word "riparious" meaning "bank" (of the stream) and simply refers to land adjacent to a body of water or life on the bank of a body of water. Following the Latin derivative, some authors exclude the aquatic component when defining riparian area and apply the root word literally, using only single factors such as soils, groundwater and surface water hydrology, or vegetative type (Karr and Schlosser 1978). Soil scientists prefer a definition based on water availability and define the riparian zone as:

> ". . . land, inclusive of hydrophytes, and/or with soil that is saturated by groundwater for at least part of the growing season within the rooting depth of potential native vegetation (Brosofske 1996)."

Riparian areas are also characterized by climate, geology, land forms, natural disturbances, soil, and vegetation (Swanson 1982). Naiman et al. (1993), offer this definition:

> "The riparian corridor encompasses the stream channel and that portion of the terrestrial landscape from the high water mark toward the uplands where vegetation may be influenced by the elevated water tables or flooding and the ability of the soils to hold water."

These concepts include the water body but exclude the high terraces and slopes that never flood, yet their falling trees and bank sediment can strongly affect channel habitats. These areas also regulate water temperature, fine and coarse organic matter input, bank stability, regulation of nutrient and sediment flows, and landscape corridor or habitat connectivity. The role of climate, geology, and land forms is widely recognized and forms the basis for hierarchical classification systems of terrestrial and aquatic ecosystems (USDA Forest Service 1993; Maxwell et al. 1995; see Chapter 3).

The presence of water and its flow pattern or regime is *the* most distinguishing characteristic of riparian areas. The delivery and routing of water, along with the transport of sediment and woody debris, are responsible for defining riparian area boundaries (Naiman et al. 1993) and are used to classify natural stream reaches (Rosgen 1996). Riparian areas, because of their landscape position, are subject both to more surface flows (runoff and flooding) and more subsurface flows (saturated soil horizons near the surface or true groundwater). Riparian areas generally have more water available to plants and animals than adjacent uplands (Gregory et al. 1991).

Soil properties in riparian areas are quite variable, ranging from saturated to well-drained over short distances (Gregory 1991), so decomposition rates are also variable. Where the soils are saturated or seasonally saturated, decomposition rates are lower than in adjacent upland soils. Riparian areas with well-drained soils have decomposition rates similar to adjacent upland soils (Gregory et al. 1991; Naiman et al.1993; Brosofske 1996). The nutrient content of riparian soils also varies. It is generally higher due to the deposition of sediment and nutrients from floods and nutrients from upland runoff (Brosofske 1996). Activities occurring in the watershed, such as farming or other land disturbances, may also influence the soil nutrient content (Lowerance et al.1984; Welsch 1991; Palone and Todd 1997).

Geologic land form, soil moisture regime, and depth to the water table are the conditions that vegetation adapts to. These interactions give rise to landscape vegetation patterns that repeat in the riparian corridor. Additionally, natural disturbances (those occurring within and away from the aquatic environment) affect riparian area plant composition, structure, and successional development. These include landslides, debris-torrents, fire, wind, and flooding (Swanson et al. 1982; Gregory et al. 1991).

Defining riparian areas more broadly is also supported by Swanson et al. (1982), Gregory et al. (1991), and Verry (1992). Gregory's (1997) recent definition of riparian areas includes the aquatic ecosystem and that portion of the terrestrial ecosystem, beyond the influence of elevated water tables, that has a functional connection to the water. Hupp and Osterkamp (1996) endorse the ecological context for defining riparian areas because doing so recognizes the importance of fluvial geomorphic processes in shaping the character of the riparian zone. See Brosofske (1996) and Palone and Todd (1997) for recent reviews of riparian area definitions.

An Evolutionary Perspective

It is not obvious how all these views of riparian-area definition should be reconciled. Yet on close examination, we see them as a reflection of how the professions dealing with riparian areas have evolved in the last three decades. First, there was a tendency to separate ecosystems by disciplines (i.e., aquatic versus terrestrial) and to separate management alternatives by disciplines (i.e., forestry or agricultural BMPs applied to land versus fisheries habitat management applied to water). Those not directly concerned with management tend to combine descriptors of riparian condition using a multidisciplinary approach. The multidiscipline ecosystem approach uses soil condition (soil science), citing saturated soils for at least part of the year combined with soil mottling. This system also combines the presence of hydrophytes (plant science) and the presence of the water table within the rooting zone as a measure of hydroperiod (water science). These same three factors are also used in defining wetlands. The emphasis in these definitions is to give each discipline an equal footing, and to separate management from science; that is, the management or multidiscipline definitions can stand alone and, perhaps most importantly, the definitions describe the state or condition of the ecosystem.

Descriptions of the state or condition of the riparian area can cause administrative confusion and can heighten disciplinary turf battles when ecosystems are mapped (see Chapter 4). How is a riparian area physically mapped, using both aquatic valley segments and terrestrial land type phases, and how are agencies or landowners to use these designations to track their resources? Both the aquatic and terrestrial ecologic classification systems (ECS) map ecosystems that are defined by climate, geology, soils, and biologic community. Concerns about mapping separate professionals seeking agreement on riparian-area definition. The most recent definitions deviate from considering only soils, plants, and water to include geologic and landscape setting and the geomorphology of streams and lakes. They focus not on ecosystem state, but on ecosystem function.

Our *functional definition of riparian area* that follows differs from those based on static state variables by using the flow of energy and materials (an ecosystem function) as the basis. Hence, movement of things is the basis for the definition rather than a fixed map unit. It uses water movement to define a stream as having a bank and bed since water must form these features almost annually regardless of whether the stream is perennial, intermittent, or ephemeral. It enhances the linkage concept between terrestrial and aquatic ecosystems universally accepted as characteristic of riparian areas. It allows state variables to be mapped using both aquatic and terrestrial ECS systems and allows overlays of riparian information on top of exclusive ecosystem map units. The management corollary is the design of roads that move vehicles, people, things, and water across both terrestrial and aquatic mapping units. It asks the questions: what linkages are important and where are they important enough to be included in a functional definition of riparian area? It includes aquatic, classical Greek riparious-riparian, and parts of terrestrial ecosystems. We consider the functional definition as an *interdisciplinary* approach that recognizes ecosystem functions developed and applied from many professional disciplines in a common landscape rather than the equal grouping of soil water and plant variables (*multidiscipline*). While we will offer guides to many aspects, professional judgment should be used as needed from site to site.

A Functional Definition

Despite these differences in riparian components and their character of components from an ecological perspective, there is agreement that a riparian area:

- Includes the water or feature that contains or transports water for a portion of the year
- Is an *ecotone* of interaction between the aquatic and terrestrial ecosystem
- Has highly variable widths or boundaries

Accepting these concepts, we offer the following functional definition for "riparian area":

> **Riparian areas are three-dimensional ecotones of interaction that include terrestrial and aquatic ecosystems, that extend down into the groundwater, up above the canopy, outward across the floodplain, up the near-slopes that drain to the water, laterally into the terrestrial ecosystem, and along the water course at a variable width.**

This definition is appropriate for natural resource management because it recognizes riparian areas by the ecological functions that occur at various scales. These regulate water temperature, fine and coarse organic matter input, bank stability, regulation of nutrient and sediment flows, and landscape corridor or habitat connection. Riparian areas are more than just buffers, and this functional definition recognizes this. As discussed by Swanson et al. (1982), a definition that incorporates scale, and recognizes the interactions that occur at each scale, enables us to address all the functions critical to maintaining healthy riparian areas (Table 2.1).

Adopting a functional definition means recognizing that the riparian boundary does not stop at an arbitrary, uniform distance away from the channel or bank, but varies in width and shape. While riparian areas can be mapped, a functional approach to delineating their boundaries is preferable to applying a uniform width. This approach is addressed in the following sections.

Moving from Definition to Delineation of Riparian Areas

Delineating riparian areas requires that we see them in a landscape perspective. Understanding the geology and landscape of the areas, and knowing their length and width, will help us define riparian areas on the ground.

Geomorphology is the Basis for Delineating Riparian Areas

Hunter (1990) considered "scale" in answering the question, " Just what is a riparian zone?" The riparian zone, at the smallest scale, is the immediate water's edge, where some aquatic plants and animals form a distinct community. At the next scale, the riparian zone includes those areas periodically inundated by high water. At the largest scale (and in forested regions), the riparian zone is "the band of forest that has a significant influence or conversely

Table 2.1 Functions of riparian vegetation with respect to aquatic ecosystems. Adapted from Swanson et al. (1982) and Nilsson et al. (1991).

Location	Component	Function
Above the ground or channel	Canopy and stems	Shade controls channel temperature and in stream primary production Source of large and fine plant detritus Wildlife habitat
In the channel	Large debris derived from riparian vegetation	Control routing of water and sediment Shape habitat — pools, riffles, cover Substrate for biological activity
Stream banks	Roots	Increased bank stability Create over-hanging bank cover Nutrient uptake from groundwater and stream water
Floodplain	Ground vegetation	Spawning for fish and for insects moving up channel Source of detritus Retards nutrient loss Reduces runoff through evapotranspiration

is significantly influenced by the stream." (In this context, Hunter uses riparian zones in a functional context (as we have used riparian areas) to distinguish from a riparian *management* zone (RMZ) often associated with Best Management Practice buffers). Landscape geomorphology constrains the stream valley, lake basin, and vegetation type (Swanson et al. 1982; Goebel et al. 1996; Naiman et al. 1997). It is in this context that we examine the physical controls on riparian functions.

Longitudinal Geomorphic Controls on Riparian Areas

The river Adour in France does not have a continuous floristic corridor because of interruptions caused by environmental factors such as climate boundaries (with elevation change or nearness to large water bodies) and the confluence of tributaries (Tabacchi et al.1990). This confirms the work of Buchholz (1981) in New Jersey where the intersection of tributaries with main-stem floodplains strongly affected the woody species distribution of the riparian area. In northeastern Minnesota, Ericsson and Schimpf (1986) show that steep streams in bedrock consistently were lined with conifer forests, while flat, glacial-till areas with lower stream slopes consistently were associated with mixed forest types. Nilsson et al. (1991) took this geology control concept further and considered whether vascular plant species richness along rivers was similar for small and large rivers in Sweden. Species richness was similar for rivers differing by a factor of tenfold in their discharge, but more importantly, greatest species richness for all rivers occurred where the channel was moderately steep and the soil moderate in texture.

The sequence of vegetation and geology interaction in a downstream direction may be reflected in a similar sequence of natural stream types (tens to hundreds of meters long) that are also based on geology (see Chapter 6). For instance, the Natural Stream Type sequence, B-C-B-C, in the Appalachians corresponds to the dominance of relatively narrow-valley, high-slope forests (B Stream Type where there is no developed floodplain) with intervening sections of wide-valley and either low- or high-slope forests adjacent (C Stream Type with a developed floodplain). Similarly the Stream Type sequence, E-G-E or E-B-E corresponds to mixed floodplain forests (E Type) versus conifer forests on steep side slopes (G, or not quite as steep, B Types) in the northern Lakes States and Maine. Forest type change may not be reflected in stream type change. Rather, only a change in site indexes or changes in shrub and herbaceous plants may occur. Riparian area width varies not only as stream width increases but also as the valley type changes along the river corridor.

Characterization of riparian forests is facilitated by incorporating the hierarchical structure of landscapes into a classification system in the same manner that terrestrial ecosystems can be arrayed and understood hierarchically (Bailey 1996). While this process is the focus of Chapter 3, it is discussed here briefly as it relates to delineation of riparian areas. In glacial landscapes, riparian and wetland forest characteristics differ among different landforms such as outwash plain and moraine (Zogg and Barnes 1995). Valley segment classifications (based on segments that are many kilometers long) account for groundwater sources, stream chemistry, and stream biology that reflects geologic position in the broader landscape (Chapter 3). The landscape setting constrains the development of stream valley or lake basin characteristics (Goebel et al. 1996). For streams, the constraining features of both the terrestrial landscape and the aquatic system on riparian area development may vary in predictable ways, from headwater streams to confluences at the bottom of watersheds, i.e., longitudinally (*sensu* Malanson 1993). Lake riparian characteristics may vary in predictable ways as well, both within individual basins (e.g., between the opposite steep and flat sides of ice-carved kettle lakes in glacial landscapes) and among different lake basins whose depth may or may not intercept aquifers with a strong groundwater flow.

In 1994, Rosgen developed field measures that quantified the relationship of a valley to a stream in terms of the energy of flowing water and used these relationships to plan the restoration of riparian vegetation (as it relates to the water table) and stream channel morphology (Rosgen 1996). Two measures are most important. First is the entrenchment ratio that is measured in transverse cross-section, and is taken as the ratio of valley width (at the elevation of the approximate 50-year flood) to the stream width (measured at the bankfull elevation). Second is the belt width ratio sometimes measured on an aerial photo or map. This is the distance between opposing meander bends over a stream section compared again to bankfull stream width. The belt width ratio is usually the larger of the two and defines how the entire stream moves across the floodplain over time. Together, the two measures allow for a distinction to be made between vegetation on the floodplain and vegetation on terraces (higher, abandoned floodplains). They define the volume of the valley filled by large floods (in the channel and across the floodplain). Why use the 50-year flood elevation rather than the 100-year flood elevation? Simply put, the 50-year elevation nearly always intersects a terrace slope or other up-sloping surface, while the 100-year flood elevation can be so high as to carry beyond glacial or climate change caused terrace elevations (Rosgen 1996).

Lateral Geomorphic Controls on Riparian Areas

Hack and Goodlett (1960) showed that riparian forests in the headwaters of Appalachia's Shenandoah River in Virginia were best correlated with slope position (reflecting how much water came to and passed through the site), soil texture (that controlled water availability above the water table), and depth to the water table. These plant community observations later evolved into the hydrologic concept of wet, riparian areas (variable in size over time) that generated storm flow in streams (see Chapter 6). Hupp and Osterkamp (1985) expanded the Virginia work at Passage Creek with an emphasis on flood plain forests, and Harris (1985, 1988) broadened the perspective to include valley and stream types as they influenced riparian vegetation in the Cottonwood Creek basin of California's eastern Sierra Nevada range.

While vegetation was described in terms of size, amounts, and diversity, geomorphic valley and stream classifications were restricted to conceptual cross sections depicting U- or V-shaped valleys, alluvial fans, and depositional flats (floodplains). Similarly, Kovalchik and Chitwood (1990) added an indeterminate depth to the water table in these conceptual cross sections to differentiate tree, shrub, and herbaceous communities. Verry (1997) quantified depth to water table using depth-duration curves and related the 50th percentile of the daily elevation of the growing season water table to maximum vegetation height development (see Chapter 5).

The geomorphic ecotone of a riparian area constrains the development of soil and plant communities (Geobel et al. 1996; Naiman et al. 1997). The mechanisms behind soil and plant development include geomorphic influences on water tables and disturbance regimes. Water table depth often greatly affects vegetation composition along aquatic to upland gradients in riparian areas (Frye and Quinn 1979; Van Cleve et al. 1993; Malanson 1993; Viereck et al. 1993). This effect may be direct through influence on water availability to riparian plants, particularly during establishment (Dawson and Ehleringer 1991). It may also be indirect through influence on soil development. As an example of the latter, a persistent shallow water table in boreal and cool temperate environments inhibits plant decomposition, resulting in organic soil formation and development of characteristic peatland plant communities (Spurr and Barnes 1980).

Disturbances affecting riparian plant communities also are related to geomorphic features of stream valleys and lake basins. Flooding controls vegetation development in some riparian areas by influencing both the establishment and the mortality of plants (Swanson et al. 1982; Harris 1987; Hupp 1988; Viereck et al. 1993). Valley floor landforms (e.g., active floodplain vs. the terrace slope) regulate the specific response of vegetation to flooding by controlling inundation depths and duration (Hupp 1988; Viereck et al. 1993). Landforms may influence fire frequency in riparian ecosystems and vegetation composition and structure (Malanson 1993).

Roots and Canopies at the Bank and on the Floodplain

Ikeda and Izumi (1990) show how strong riparian vegetation roots will deepen and narrow gravel-bed rivers in North America, Europe, and Japan. When stream shoot cutoffs occur at meander bends, a strong living, pre-existing root system, several channel widths away from the original channel will ensure that new channels are shaped to the modal width/depth ratios for natural streams and that they will not become overwide and more shallow. Similarly, Parker (1978a,b) explained the concept that allows the coexistence of mobile streambeds and immobile bank regions in gravel-bed and sand-silt rivers by examining the relationship of sediment shear stress in the streambed and shear stress on streambanks. It is common for streambeds to scour up to several feet each year during bankfull flows and redistribute themselves with the riffle, pool pattern and sediment size distribution that existed before the bankfull flow.

In contrast to these two reviews that consider the entire floodplain and the movement of meandering stream channels over time, many studies and reviews have focused only on site-specific aspects of bank stability and conclude that streambank stability involves trees mostly within one-half tree-height of the bank (O'Laughlin and Belt 1995). Many studies and reviews also address large woody debris recruitment as a streambank phenomenon and suggest the source for most coarse woody debris recruited into a stream is often the riparian forest within one tree height of the bank; however, many of these have been done on entrenched stream systems with small or nonexistent floodplains (O'Laughlin and Belt 1995) (see also Chapter 7). Floodplain streams (with low valley entrenchment) recruit woody debris from the entire floodplain. Tree stems on the floodplain regulate the flow of woody debris to the stream channel in these stream types by catching floating wood just as wood in the stream channel regulates the flow of leaf litter. Thus, maintenance of living root systems and tree stems on the floodplain will allow channel cutoffs to produce new channels with normal channel dimensions and moderate the occurrence of log jams in the channel. Where water tables are high enough to exclude trees, grasses and sedges protect streambanks equally well if exposed banks contain sufficient root mass (Pfankuch 1975, Rosgen 1996).

Dick (1989) used spatial modeling of stream temperatures to show that the shade effect is derived partly from riparian elevation and slope and partly from vegetation canopies. Similarly, Sinokrot and Stefan (1993) showed that stream bottom color and the slowing of wind by the riparian canopy (tree, shrub, and herbaceous) also influence stream temperature (about 2/3 shade related and 1/3 related to the slowing of hot winds).

Using Riparian Functions to Delineate Riparian Areas

Defining riparian areas functionally (by the movement of material and energy between the land and water) avoids problems associated with assessing whether a terrestrial setting is part of the riparian area based solely on soils, or vegetation, or frequency of flooding. A functional definition implies several important things to remember when developing riparian area management prescriptions. The width of riparian functions:

- Are greater than the area associated directly with floodplain or wetland indicators
- Will vary with the function being considered
- Will be difficult to determine with certainty for some functions

The extent of a riparian area into the terrestrial setting varies with the strength of each function rather than at a fixed distance from the water. The number of functions contributing to riparian and aquatic ecosystem processes decreases with distance from the water ecosystem (Figure 2.1). But the distance at which a particular function is no longer important may be difficult to determine with certainty. This is why professional judgment should be used as needed from site to site.

Finally, a functionally delineated riparian area may not, and likely will not, translate directly into a riparian management zone designed to "buffer" the stream, but is usually larger. Riparian management buffers are designated where special silvicultural and operational considerations are needed. The size of the management buffer will depend on specific aquatic and terrestrial conditions; on the proposed practices and resultant impact of the management practices; and on the consensus reached in a particular organization or government division.

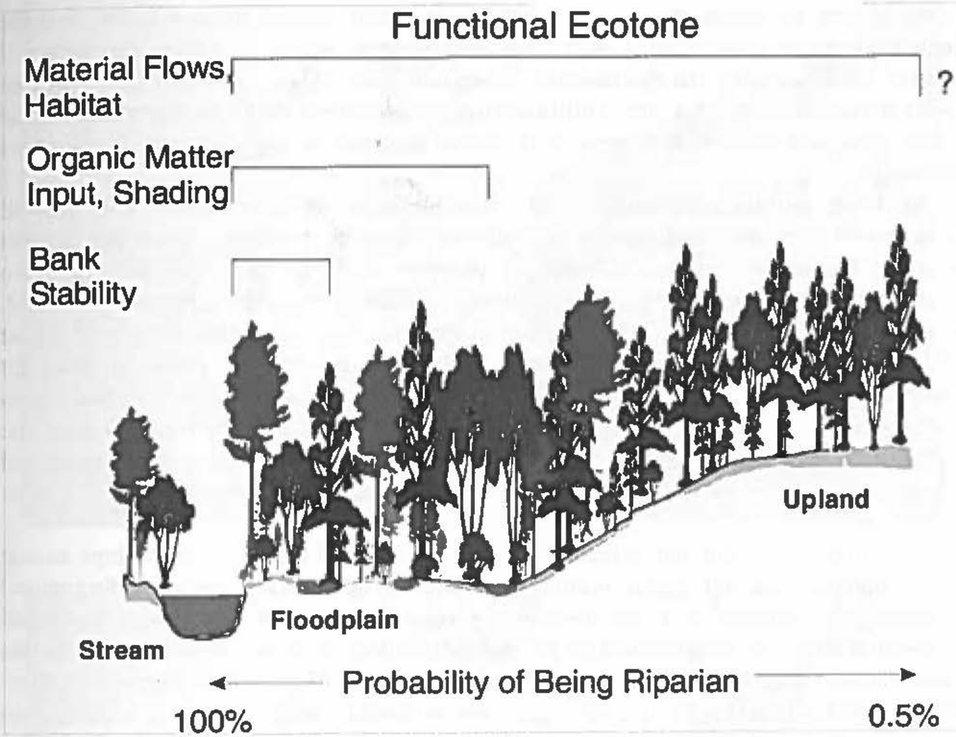


Figure 2.1 The probability of a function being riparian varies with each function across the riparian ecotone.

On the ground assessments of riparian area width based on functionality would be costly and complex, if not impossible, for natural resource managers. Indeed, research on riparian functional delineation has lagged behind the need managers have to locate and delineate riparian areas. Geomorphology is a likely surrogate for some functions that can be easily measured, either directly on the ground or from existing data. Few studies of riparian forest characteristics have been conducted with the transverse geomorphic structure of the riparian area in mind. Like riparian management zones, most riparian studies have been conducted with data plots at fixed distances from the water rather than by geomorphic position (floodplain, terrace, low terrace, tributary junction, etc.). This transverse structure reflects constraining geomorphic influences of both the upslope (terrestrial) and downslope (aquatic) environment. Understanding it will facilitate delineating riparian areas to capture the true extent of their functionality. Stream valley or lake basin geomorphology is the basis for delineating the riparian ecotone. Modeling relationships between condition variables and riparian functions will assist riparian area delineation based on land features rather than those based on lines at a fixed distance. Until such models are widely available, understanding the geomorphic ecotone of riparian areas is a practical approach to on-the-ground, riparian-area delineation.

In stream settings, recognizable and repeatable valley floor landforms reflect fluvial processes of deposition and erosion. Similar sequences of landforms define the riparian ecotone of lacustrine systems, although the processes that form them are different. Two points need to be remembered when identifying riparian geomorphic ecotones in the field. First, not all landforms occur in all riparian systems, and some landforms may repeat themselves within the same system. For example, an easily definable floodplain does not occur in steep-sided stream valleys, and multiple terraces occur where river or lake levels have dropped repeatedly, i.e., forming abandoned floodplains and lake beds. Second, the geomorphic features of the upland end of the riparian ecotone are often considered terrestrial in origin but may have been formed by the action of water, such as through glacial or marine deposition.

Quantifying the ecotonal structure of riparian areas and the interrelationships among geomorphology, soil, and vegetation along this gradient is necessary for understanding natural variability in structure and function among riparian areas for developing functional delineation criteria of riparian area width; and for developing options for managing riparian areas. With these goals in mind, a practical approach to delineation that inherently captures the geomorphic structure of riparian ecotones is outlined in the final section. Take time to consider how the scale of a riparian area affects your judgment of its extent (See Figure 2.2 for an example of scale effects).

Identifying Functional Riparian Areas on the Ground

Stream channels have a defined bank and a scoured bed whether they have water in them or not. Many are associated with a floodplain where the channel water spills at the flood stage (the bankfull elevation). Floodplains are deposition areas and regularly receive the sediment of the stream's valley. Terraces are abandoned floodplains and occur at a higher elevation than the active floodplain but may have been deformed over time by slumping. Abandoned stream channels on active floodplains or terraces are common.

Terraces more than 3 to 6 ft above the floodplain were likely caused by channel down-cutting as the result of climate change, glacial action, or regional changes in the base level of rivers (e.g., the glacial Great Lakes escaping to the Atlantic Ocean, or tectonic uplift). Lower terraces can be caused by land-use changes; in severely eroded landscapes, land-use change

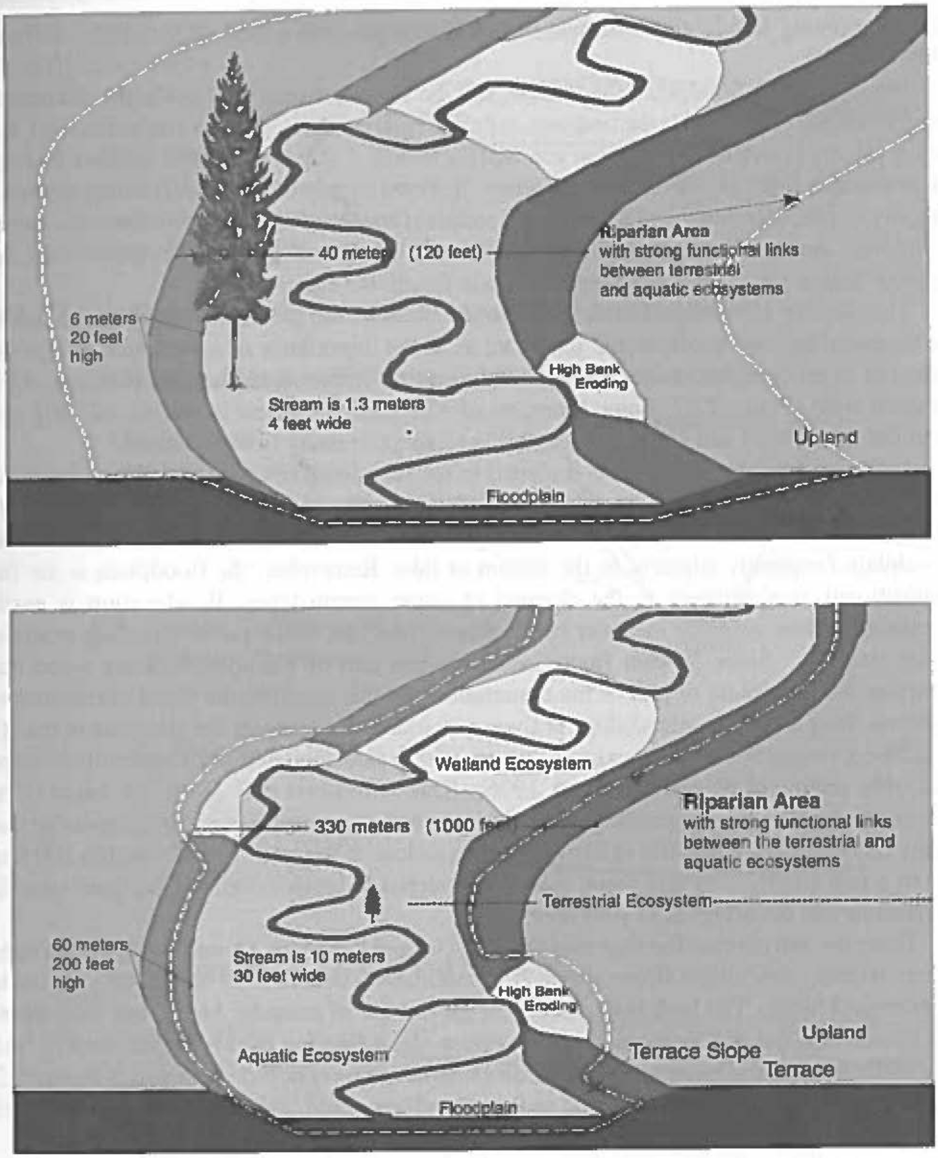


Figure 2.2 This diagram shows how the scale of the stream and its valley impacts the delineation of a riparian area. The relative scale of the stream width and its valley are the same in each frame.

can fill existing floodplains with 6 ft of new sediment (Allen 1965; Knox 1977; Trimble 1983).

Identifying the floodplain, the terrace, and the slope between the floodplain and terrace (terrace slope) in the field is the best way to define riparian areas. "Learn to read the land, and when you do, I have no fear of what you will do with it..." (Leopold 1949). Always look for these features first. However, in some areas, the flood simply flows between steep mountain or gully slopes, carrying the sediment to a floodplain at a lower elevation; in others the slopes away from the stream or lake are so slight that only a continuum is seen. In these cases, the rules of thumb given below can help delineate functional riparian areas.

This key for identifying functional riparian areas on the ground are guides, and should be tempered by your professional judgment as to the importance of a particular ecosystem function (a process that moves material between the terrestrial and aquatic portions of the riparian area) (Figure 2.3). Some examples of where this judgment is needed will help you read the land (river) and allow you flexibility to adapt to many field situations.

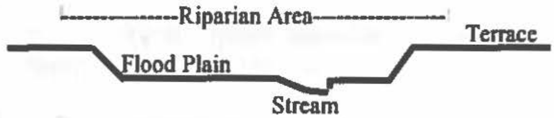
Let's consider the components included in the functional riparian area. First, the water body is always included (stream, lake, pond, wetland). Second, the floodplain of streams is always included (and the highwater area of lakes), as well as the wetlands within the floodplain frequently adjacent to the stream or lake. Remember, the floodplain is the flat depositional area adjacent to the channel of some stream types. Its elevation is easily identified on the *inside* of meander bends where the slope of the point bar rising from the water flattens. Since 50-year floods also inundate part of the upland terrace slope that confines the floodplain or part of the mountain slope that confines the flood in entrenched systems, this part of the upland slope is always included. To estimate the elevation of the 50-year flood, simply double the maximum channel depth measured below the bankfull elevation at a riffle section of the river (Rosgen, 1996). This "two times max depth" elevation is the 50-year flood elevation (+ or - 10 years). This information is tempered by the knowledge that many functions reach 60-80% of their importance close to the water, usually within 100 ft or about a tree length. At this point, your professional judgment needs to evaluate specific conditions and occurrences in your area.

First, we will discuss the first two On-The-Ground key items (A and AA/B) describing where terrace or mountain slopes occur. It is important to consider the high bank adjacent to streams and lakes. The high bank occurs on the *outside* of meander bends, but only where the stream channel is flowing against the terrace slope (the top of this terrace bank is well above the floodplain elevation). A common example of this condition is shown in Figure 2.2. From this figure, it is easy to see that sediment and trees from the high bank produce much of the stream sediment and large woody debris. But not all meander bends occur at the terrace slope; many terrace slopes are far from the channel in large stream systems. Remember that all floods will flow against all terrace slopes but that channel bank erosion will be concentrated where the meander bend flows against the terrace slope. You can decide whether to include these high banks cut into the terrace slope and a tree length at their top.

A. Floodplain & Terrace Slopes Are Identifiable

The Riparian Area consists of:

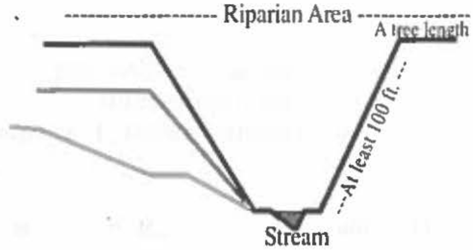
--The Stream
--The Floodplain
--The Terrace Slopes adjacent to the floodplain
--One Tree Length on top of each terrace



AA. Either Floodplain Or Terrace Slopes NOT Identifiable

B. Slopes Steep (> 5%) adjacent to stream or floodplain

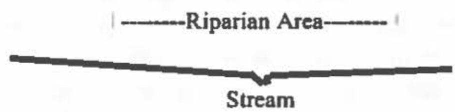
--The Stream
--The Slope to its top
--One Tree Length beyond slope top



BB. Slopes Gentle (<5%) adjacent to stream or floodplain

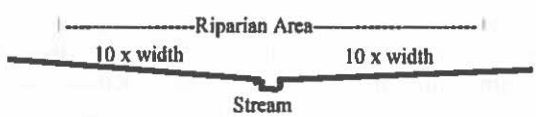
C. Streams <10 ft Wide at Bankfull

--The Stream
--One Tree Length on each side



CC. Streams >10 ft Wide at Bankfull

–The Stream
–10 X bankfull width, each side

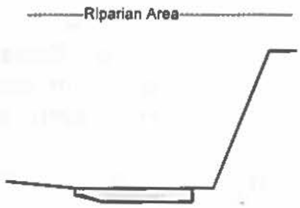


(May approach 20 X stream width for E type channels with wide floodplains, see Chapter 6)

Figure 2.3 Field key to define riparian areas for streams.

A. **Slopes Steep (>5%)**
adjacent to lake or wetland

--The Lake or Wetland
--The Slope
--One Tree Length
beyond slope top



AA. **Slopes Gentle (<5%)**
adjacent to lake or wetland

--The Lake or Wetland
--One Tree Length
beyond ordinary high water mark

Figure 2.3 continued. Field key to define riparian areas for lakes and wetlands.

Whether you include all terrace slopes and tops or only part of them depends on the size of the valley. For small streams and valleys (say, streams 10 ft and valleys 300 ft wide), you may want to include all terrace slopes and terrace tops because leaf recruitment, for example, and many other functions are important to an arbitrary tree length of at least 100 ft. Where the stream and its valley are wider, you may want to exclude those upper terrace slopes above the 50-year flood elevation where the stream itself is far away from them.

Professional judgment is also needed to predict how changes occur over time. Meander-bends, for example, move down-valley with time. In many situations this happens so slowly that their location against the terrace wall appears static, even though they are moving downstream. In certain situations where land-use changes are rapid, or where reservoir operation impact reaches downstream, the meander migration rates may accelerate, resulting in significant changes within a decade. Know your situation.

Landslides and slumps can occur at these high bank locations in floodplain stream systems and frequently occur in mountain stream systems without floodplains where adjacent mountain slopes are steep and soils unstable. These slumps can extend 300 ft above the stream. Thus, how far you extend the functional riparian area up steep, high slopes will depend on the occurrence of slumping in your area. Extend the functional riparian area at least 100 ft vertically, regardless of their slope. Similarly, high slopes may be interrupted by a series of old glacial or climatic terraces. You must decide how many, if any, of the terraces are included in your functional riparian area. Similar conditions occur adjacent to lakes, frequently one side of a lake will have a steep slope formed by ice pushing up a tall moraine, and the other side will have a gentle slope formed by ice scraping the landscape nearly level.

For water bodies with gentle adjacent slopes (< 5%; key level AA/BB/C or CC), a simple rule of thumb is applied to estimate the meander-belt width that may not be obvious. Meander belt ratios can vary from 2 to 80 (Rosgen 1996); however, the lowest values are associated with highly entrenched systems where mountain slopes constrain the stream system, and the highest values are associated with some of the E stream types that have wide floodplains. Many of these have grasses, sedges, or shrubs; but where water tables are low enough, they are forested. Since the key should be used in series (first item first, etc.), the lower meander belt ratios are already considered in the first two key items (A and A/BB). This leaves only moderate- to high-meander belt ratios to consider for the water bodies with gentle adjacent slopes.

Judgment should be used when using the gentle-slope rule of thumb. First, remember that the meander-belt ratio accounts for the entire meander belt — it includes both sides of the stream. And in referring to Figure 2.2 it is obvious that the stream does not always (actually rarely) flow in the middle of the meander belt. Where you *cannot identify* the actual meander belt (floodplain and terraces), *define the functional riparian area as 10 x Bankfull Width on each side of the stream.*

This rule of thumb is half the meander belt ratio of 20 which includes all C stream types and the low end of E stream types. E channels are typical in low-slope eastern forests as are C stream types. Also, realize that we have already used some professional judgment in making the division between key level C and CC. If we assume a tree length is 100 ft and that many of the shade, woody debris recruitment, bank stability, and litter fall functions approach 60 to 80% of their maximums within 100 ft, then the rule of thumb is overridden by these considerations when streams are small (10 ft wide or less). For larger streams (> 10 ft wide at the bankfull elevation), the importance of the flooded area should also be considered. Lake and wetland guides are identical to stream guides, but gentle or steep adjacent slopes may, and often do, occur on opposite sides of the same water body. In time, we have no doubt you will be able to read the land and the river, and we have no fear of what you will do for them.