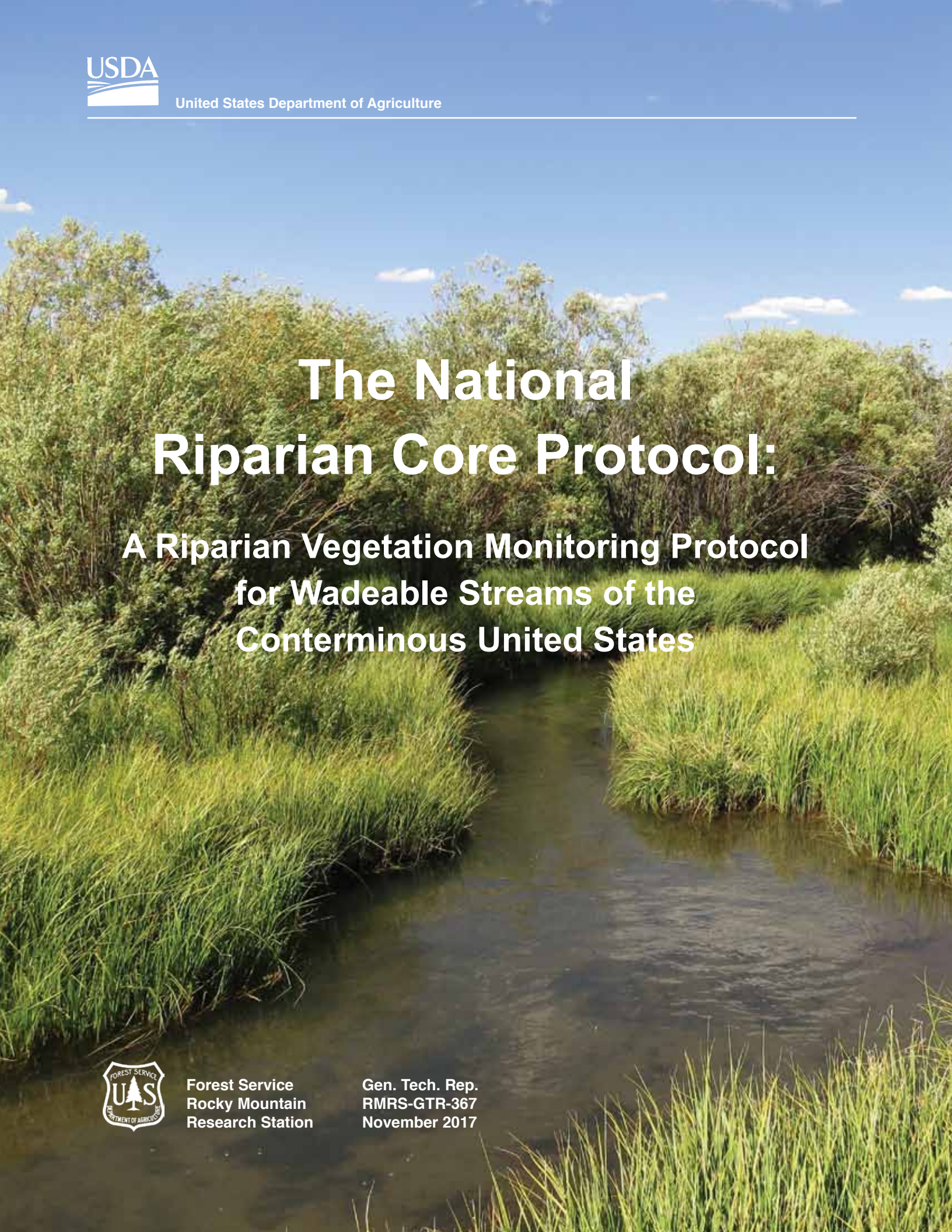

United States Department of Agriculture

The National Riparian Core Protocol:

A Riparian Vegetation Monitoring Protocol for Wadeable Streams of the Conterminous United States

Forest Service
Rocky Mountain
Research Station

Gen. Tech. Rep.
RMRS-GTR-367
November 2017

Merritt, David M.; Manning, Mary E.; Hough-Snee, Nate, eds. 2017. **The National Riparian Core Protocol: A riparian vegetation monitoring protocol for wadeable streams of the conterminous United States.** Gen. Tech. Rep. RMRS-GTR-367. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 37 p.

Abstract

Riparian areas are hotspots of biological diversity that may serve as high quality habitat for fish and wildlife. The National Riparian Core Protocol (NRCP) provides tools and methods to assist natural resource professionals in sampling riparian vegetation and physical characteristics along wadeable streams. Guidance is provided for collecting basic information on riparian vegetation composition and physical structure in fluvial riparian ecosystems. The NRCP provides a foundation to assess the characteristics and condition of channels and riparian vegetation at a single point in time or in response to changes in land- and water-use activities, including restoration, or natural processes through time.

Keywords: floodplains, monitoring, protocol, riparian vegetation, valley bottom classification, vegetation assessment, wadeable streams

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Acknowledgments

We thank these National Forests for reviewing, testing, and providing feedback on the National Riparian Protocol: Hiawatha, Malheur, Umatilla, Wallowa-Whitman, San Juan, Green Mountain, White Mountain, Medicine Bow-Routt, Allegheny, and Daniel Boone. Jessie Salix (Beaverhead-Deerlodge National Forest) and Brett Roper (National Stream and Aquatic Ecology Center) provided excellent reviews of the concepts and methods presented in the final protocol. Additionally, we thank the National Riparian Service Team for reviewing the protocol, and Colorado State University for developing, testing, field validating, and providing classification map products of the Hydrogeomorphic Valley Classification. We thank Linda Spencer for helpful dialogue regarding riparian resources and monitoring. We thank Constance Lemos, Patricia Cohn, and Lane Eskew for providing editorial assistance on behalf of the Rocky Mountain Research Station.

The use of trade or firm names in the publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

At a Glance

Why a National Riparian Protocol for the Forest Service?

The purpose of the National Riparian Protocol is to provide guidance on sampling riparian vegetation and physical characteristics along wadeable stream channels and their associated floodplains and valley bottoms. Many riparian areas have been altered or degraded by historic and current land use and alterations in the timing, magnitude, and duration of peak and minimum flows. These land- and water-use patterns shape channel and streamside landforms and the composition and structure of the associated vegetation. There is a need for a basic, flexible protocol that provides a foundation to assess the composition and physical structure of riparian vegetation so that riparian condition can be explicitly linked to land- and water-use activities. The same protocol can be used to monitor riparian ecosystem change following restoration activities or natural disturbances.

What is the National Riparian Core Protocol (NRCP)?

This NRCP is a basic protocol designed for sampling ecologically important characteristics of riparian areas at the reach scale, including: (1) species composition, (2) vertical structure of vegetation, (3) size-class structure of trees, and (4) physical channel characteristics. The NRCP is intended to guide land managers in gathering riparian data so that they may make comparisons among multiple reaches or track the trajectory of reaches' vegetation composition and structure over time. This core protocol provides a flexible framework that can be used to collect basic information on riparian vegetation composition and structure for reach characterization, and/or used as the foundation of a long-term monitoring program that is implemented to answer specific management questions. The NRCP complements existing agency protocols for monitoring riparian vegetation resources and may be paired with aquatic and fishery-related protocols when larger biological inventories are required.

Who was the protocol designed for?

The protocol was designed for resource managers who are undertaking objective-based riparian monitoring and for those tasked with monitoring riparian vegetation to track changes through time. This NRCP was designed for botanists, plant ecologists, rangeland scientists, foresters, hydrologists, and other resource specialists. With proper training, it can be carried out in the field by biological or hydrological science technicians. Because streams and their riparian areas are complex systems, teams of multiple resource specialists with plant or forest ecology, hydrology, and/or geomorphology backgrounds will be able to most effectively implement the protocol and pair the resulting data with meaningful hydrologic and/or watershed disturbance data.

Where can the protocol be applied?

The methods outlined in the NRCP are intended for use on a variety of stream types and within a variety of valley settings. Flexibility is deliberately built into this protocol, and the manager must tailor the methods to specific sites, settings, and conditions to best meet project objectives. Monitoring plans tailored to meet clearly defined objectives under a well-defined scale, scope, and area of interest are essential to collecting informative riparian vegetation data.

What types of disturbances or land management issues can this protocol be used to monitor?

The protocol can be used to effectively assess riparian vegetation responses to multiple disturbances. These include, but are not limited to:

- How riparian vegetation changes across hydrologic gradients and fluvial landforms along a given stream reach;

- How natural (insect, herbivory, disease), fluvial (stream-related), or human-caused disturbance shapes vegetation composition over time; and
- The effectiveness of stream or riparian restoration in recovering desirable attributes of riparian vegetation, including composition, structure, habitat value, and individual tree fitness.

Additional methods are available to augment this core protocol. Guidance for adding measurements to meet specific objectives, such as characterizing grazing impacts, quantifying habitat characteristics, and determining the effects of vegetation removal, etc., are referenced below and can be found in the more extensive USDA Forest Service Riparian Monitoring Protocol Technical Guide, Merritt, David M.; Manning, Mary E.; Hough-Snee, Nate. In preparation. The riparian vegetation monitoring technical guide: Rationale, guidance, and methods for sampling wadeable streams. Gen. Tech. Rep. RMRS-GTR-XXX. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 187 p.

What are the value-added applications of the protocol? Can the protocol be integrated with existing hydrologic, fisheries, aquatic, wildlife, and rangeland monitoring applications?

Data collected under the NRCP may fit into existing monitoring efforts on many forests, including monitoring already being conducted for rare and endangered plants, fish or benthic macroinvertebrate community composition and abundance, stream habitat (geomorphic) surveys, water quality, wildlife community composition and abundance, and grazing impacts. In many cases, vegetation data collected with this protocol can be used to inform studies or report the condition of habitat and stream-related natural resources. The data collected with the NRCP can be modified to effectively characterize riparian ecosystems for many National Forest planning purposes, including National Environmental Policy Act (NEPA), National Forest Management Act (NFMA), and Endangered Species Act (ESA) analyses.

Are additional resources that augment the core protocol available for Forest Service staff?

The USDA Forest Service Riparian Monitoring Protocol Technical Guide will be available in 2018. This guide provides background on fluvial geomorphic, hydrologic, and ecological principles and processes for scientists with a general background not focused on rivers. Both the Core Protocol and Technical Guide are to be accompanied by a training video in 2018.

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The National Riparian Core Protocol: A Riparian Vegetation Monitoring Protocol for Wadeable Streams of the Conterminous United States

Edited by David M. Merritt, Mary E. Manning, and Nate Hough-Snee

Overview

Riparian areas, the interface between aquatic and terrestrial environments, are often physically heterogeneous and biologically diverse, and they may have high rates of species turnover over time relative to surrounding uplands. Riparian ecosystems provide critical habitat for aquatic, semi-aquatic, and terrestrial plant and animal species, but they have also been historically degraded from land use, flow alteration, and invasive species. Although there is an urgent need to understand their spatial extent, condition, structure, and function, the dynamic nature of stream channels makes sampling, monitoring, and evaluating riparian vegetation challenging. This difficulty has given way to the development of standardized riparian monitoring methods within many land management agencies.

This document describes the USDA Forest Service's National Riparian Core Protocol (NRCP), which provides guidance on measuring riparian vegetation and channel characteristics along wadeable stream channels and their associated floodplains and valley bottoms. This core protocol is designed to guide plant ecologists and botanists, rangeland scientists, foresters, hydrologists, and other resource specialists in gathering data to assess (1) riparian plant species composition across multiple canopy and ground cover strata and (2) channel conditions at the reach scale. When employed at a single point in time, the data collected with this protocol can be used to compare plant species composition and riparian conditions among multiple reaches. When conducted repeatedly at a single reach (or a set of reaches), riparian condition can be assessed through time to track trends in riparian plant species composition and structure.

Numerous methods have been developed for measuring riparian condition for a given stream type and set of objectives, such as looking at the effects of grazing or water withdrawal on riparian vegetation. Such methods are often adequate for achieving specific goals along the stream channel types for which they were designed. However, there is no protocol that is optimal for every stream and every purpose. Monitoring protocols, including the NRCP, should be tailored to meet clearly defined objectives—that is, to answer specific questions—across clearly defined spatial and temporal scales, within a specified geographic area of interest. This core protocol is designed to measure key characteristics of riparian areas that include: (1) species composition, (2) vertical structure of vegetation, (3) size-class structure of trees, and (4) physical channel characteristics.

The methods outlined within the NRCP are intended for use on a variety of stream types and valley settings across the conterminous United States. These methods include workflows for:

- using geospatial data to identify valley trend and valley types, stream segments, and individual reaches for sampling,
- establishing vegetation transects and channel cross-sections,
- sampling vegetation strata and substrate characteristics using the line-point intercept method,
- sampling tree and shrub composition, size structure, and condition, and
- surveying channel cross-sections and reach longitudinal profiles.

The core protocol has been designed to be flexible, and it is necessary for the investigator to tailor the methods to specific sites, landscape settings, environmental conditions, and project objectives. The number of transects, spacing of transects and/or points per transect, and specific sampling techniques may need to be modified for specific projects.

The approaches outlined in the NRCP, while flexible, are predicated upon several guiding assumptions:

- Monitoring design, data collection, analyses, and interpretation are conducted or supervised by a qualified plant ecologist, preferably one with experience working in riparian areas.
- Prior to any field data collection, sample reaches that address the monitoring question have been carefully selected using Geographic Information Systems (GIS) data, aerial photographs, topographic maps, and/or field reconnaissance.
- Each sample reach is comprised of a distinct and continuous valley type, geomorphic setting, and stream type.
- The sample reach is not located at a tributary junction.
- For longitudinal monitoring, reaches will be sampled repeatedly and consistently through time. This means that reach endpoints (top-of-reach, bottom-of-reach) should be permanently marked and easily relocated. As will be discussed below, repeated random (probabilistic) sampling of a reach is advised if the channel is likely to change locations over time through channel migration, avulsion, channel rerouting as a part of restoration, etc.
- Other factors influencing plant species composition such as livestock grazing, mechanical disturbance, wildfire, etc., are identified prior to monitoring and accounted for in data analysis and interpretation.

The NRCP provides a simple, flexible framework for collecting riparian vegetation composition and structure for reach characterization, and/or as the foundation of a long-term monitoring program that is employed to answer specific questions. Accordingly, this document is organized to guide land managers through the NRCP process, from identifying sample units and sampling intensity in the office, to data collection in the field, and from raw data to insightful analyses. Additional methods are available to augment this core protocol and guidance for adding measurements that meet specific objectives, including characterizing grazing impacts, quantifying aquatic habitat characteristics, determining the

effects of vegetation removal, etc. These are provided in the larger USDA Forest Service Riparian Vegetation Monitoring Technical Guide (hereafter Riparian Technical Guide; Merritt et al. In preparation).

Site Selection and Reach Determination

For a given application of the protocol, the valley extent and type, stream segment, and stream reaches that will be sampled should be identified in the office prior to sampling. The valley type through which a stream flows is determined by valley slope, width, form, and geology. Valley type constrains the range of stream channel forms that may occur along a stream segment, which in turn governs stream physical characteristics and the riparian vegetation that may occur at a site. When selecting reaches for sampling, the first stratification that should occur among candidate reaches is the identification and organization of the stream segment or channel network by valley type.

There are several valley bottom and valley type classifications and geospatial tools available to land managers, including the Hydrogeomorphic Valley Classification (HGVC) framework of Carlson (2009), which identifies different valley types across which riparian samples can be stratified or paired and reference conditions established. The HGVC framework takes a process-based approach to identifying valley bottoms, is freely available, and was created in collaboration with Forest Service scientists, making it ideal for application on National Forest System lands. The HGVC identifies nine valley types for the western United States:

(1) headwater,

(2) high-energy coupled,

(3) high-energy open,

(4) gorge,

(5) canyon,

(6) moderate-energy confined,

(7) moderate-energy unconfined,

(8) glacial trough,

(9) low-energy floodplain.

Different valley types occur in different landscape settings and support streams with different energy potential, physical character, and hydraulic behavior under different flows. Due to inherent differences within and between streams, the sampling layout, number and length of transects, and other measurements will vary by valley type (Frissel et al. 1986; Poole et al. 1997). Applying an initial classification of valley types within the study area is important so that replicate reaches along a segment are of similar valley form. When control or reference segments are compared to impacted segments, both segments should occur within the same valley type.

At this time, HGVC data are available through the U.S. Forest Service ArcGIS Online portal *National Riparian Protocol* group at: http://usfs.maps.arcgis.com. Documentation for the HGVC is provided in Carlson (2009) and at the U.S. Forest Service ArcGIS Online portal.

In addition to the HGVC, additional valley classifications, such as the Rosgen Valley Classification (Rosgen 1996), or mapping tools, such as the Landscape Scale Valley Confinement Algorithm (Nagel et al. 2014) or the Valley Bottom Extraction Tool (Gilbert et al. 2016), may be used to place reaches in a watershed context (Frissell et al. 1986) and refine the extent and type of valley that is mapped and to stratify reaches by their valley type within a sampling design. Regardless of the valley classification used, the sample reaches selected for comparison should occur within the same distinct and representative valley forms. If using the HGVC or other geomorphic classifications to classify valley types is not possible, then managers can measure valley width and slope from digital elevation models such as the USGS National Elevation Dataset. Quadrangle maps may be used to stratify reaches by valley width and channel slope and coarsely define valley types when GIS topography data are unavailable.

After identifying reach types and extents, valley bottom polygons from the HGVC or other valley bottom delineations should be intersected with the stream segment and sample reaches. Using GIS, Google Earth, or equivalent software, managers should draw a centerline over the valley extent that parallels the valley direction and/or valley walls. This valley centerline outlines how valley direction changes from the top of a valley to the bottom, and dictates how transects are placed perpendicular to the valley extent for stream sampling (Appendix 1).

Identifying Stream Segments and Reaches

A valley segment is the length of stream of interest. It is typically several-to-many stream reaches in length (Bisson et al. 2006; defined below). For most Forest Service monitoring applications, a relevant valley segment is likely to be the portion of stream located upstream or downstream from a point of impact such as a dam, diversion, or grazing allotment; a length of stream between tributary junctions where channels converge; or any portion of a stream consisting of multiple sample reaches at which inference is to be made. When riparian vegetation across multiple stream segments is compared, those segments should be within similar valley and channel forms. Stratifying segments into different valley types and selecting reaches of a uniform channel form are important in controlling for variability within segments and reaches so that changes in riparian attributes are detectable.

For the purposes of this protocol, a reach is defined as the downstream channel length equivalent to 20 active channel widths. The reach is a conventional unit used in geomorphology for channel measurement and classification (Montgomery and Buffington 1997), making it a similarly intuitive and consistent unit for riparian vegetation and channel sampling. The reach should encompass several sequences of repeating channel forms (geomorphic units) such as pool-riffle, step-pool, or meander-point bar-cutbank sequences. Reaches should be randomly or systematically located along a stream segment so that inference can be made to the entire segment or similar, unsampled stream segments so that these segments can be compared.

Reach locations along a valley segment of interest should be determined by choosing a random initial point along the segment's valley centerline and:

(1) systematically choosing an evenly spaced downstream interval for sample reaches, or

(2) subjectively sampling representative channel types along the segment.

Table 1—The office workflow for identifying valley types and extent and estimating transect placement prior to field sampling.

Activity	Data or tools used
Valley classification for reach stratification	Hydrogeomorphic Valley Classification or other valley bottom classification data; GIS topographic data
Valley bottom delineation and valley bottom centerline trend identification to determine transect placement	GIS valley bottom mapping software or data; USGS quadrangle maps
Roughly estimating transect location and trend perpendicular to the valley centerline along a stream segment	GIS orthophotos that include stream channel images; Hydrography datasets
Identifying stream types and stream channels with transect placement exceptions	GIS orthophotos; Wetland or water body GIS data that identifies floodplain meadows, beaver complexes, etc.

Subjective sampling, while it may target specific landforms, limits the inference that can be made about riparian condition only to the sampled vegetation points, not the entire reach. If randomly or systematically selected reaches encompass either more than one valley type or a significant change in channel characteristics, reaches should be relocated upstream or downstream until a uniform reach has been identified.

The valley, segment, and reach locations at which sampling will occur should be identified in the office prior to field work by attributing a shapefile with the valley trendline (centerline) over valley maps or topographic data (table 1). The upstream and downstream extent of stream segments should be identified on GIS hydrography data, aerial imagery, or contour maps. Digital orthogonal aerial imagery (orthophotos), like those available from the National Agricultural Imagery Program (NAIP), ArcGIS base maps, or Google Earth, should be used to identify the upper and lower extent of valley segments and confirm the orientation of the valley centerline, to systematically or randomly locate stream reaches within a segment, to determine channel dimensions, and to coarsley delineate riparian boundaries.

Sample Units and Sampling Intensity

After determining the valley type and identifying the stream segments and types of reaches of interest, a subset of the total number of possible reaches along a segment is selected for sampling. Each selected reach is a sampling unit. To effectively represent a stream segment, a minimum of three reaches (sampling units) should be identified. At each reach, multiple transects are established for vegetation and channel sampling perpendicular to the valley trend line. The number of transects established along a reach and the number of plots or points along each transect will inherently vary as a function of the objectives of the project.

The goal in choosing the number of reaches and sampling points is to obtain a sample size that provides sufficient information to address the issues of interest, to provide enough statistical power to test specific hypotheses, and to discern patterns. Sampling effort should be designed considering the objective(s) of the study, such as whether sampling is designed to characterize vegetation composition, provide a thorough inventory of riparian plant species, or identify subtle changes in vegetation across environmental gradients and between

systems. Analyses of community composition should rely on species-area curves (fig. A5.1) or other methods to ensure adequate sampling to answer study questions. An ideal sample size will have sufficient data and statistical power to answer the question of interest without oversampling and spending unnecessary time, resources, and effort on data collection.

For wadeable streams, a minimum of five transects and 200 points per reach are recommended, although more points are preferable, especially in structurally or biologically diverse settings. Closely spaced points will detect fine-scale changes in vegetation across floodplains with many different landforms, while widely spaced points may miss this variation. Distances between points should not exceed 5 m. Along wide valleys, this may result in far more than 200 sample points, so longer sampling times are required for larger valley bottoms. For analysis and comparison among reaches, the sampled points collected along a single transect that occur on a particular fluvial surface (e.g., floodplain, bank, terrace, or island) are the statistical (sampling) unit. The subsampled presence-absence data from each point are pooled by reach, and reach-level data are pooled by fluvial surface for comparison. Data should be gathered systematically across the entire valley bottom and not weighted or otherwise altered to specifically oversample or undersample fluvial surfaces. The dataset will be stratified during analysis after fieldwork is complete.

As previously mentioned, reduced sampling intensity may be required for riparian characterization compared to hypothesis testing in a hypothesis-driven experimental design. The intensity of sampling and optimal allocation of effort between subsampling reaches and sampling more reaches will also be constrained by:

(1) heterogeneity in channel form and vegetative attributes such as species presence, cover, density, frequency, etc.,

(2) achieving an adequate sample size (with the reach as the sample unit) to detect change in some variable of interest,

3) factors such as available resources and site accessibility.

If there is variation within a segment that is not necessarily of interest for monitoring, such as changes in channel form, fence lines that indicate different land use, or some other confounding reason for vegetation change, then a single reach should not straddle the multiple impact zones. For example, if characterizing vegetation across a reach, then sampling continuously across a fence line that separates grazed portions of a reach from ungrazed portions would confound the data and thus be uninformative.

Riparian Area Determination

The edge of the riparian area is determined using three criteria:

(1) *substrate attributes*—the portion of the valley bottom influenced by fluvial processes under the current climatic regime,

(2) *biotic attributes*—riparian vegetation characteristic of the region and plants known to be adapted to shallow water tables and fluvial disturbance, and

(3) *hydrologic attributes*—the area of the valley bottom flooded at the stage of the 100-year recurrence interval flow (Ries et al. 2004). The 100-year recurrence flood stage occurs at a higher magnitude discharge with a higher flood recurrence time interval and should be delineated using a combination of GIS and field methods.

Specific substrate, biotic, and hydrologic attribute criteria are detailed in the Riparian Technical Guide (Merritt et al. In preparation). They are similar to the three parameters—soils, hydrology, and vegetation—used to delineate jurisdictional wetland boundaries in the United States for management under the Clean Water Act (Environmental Laboratory 1987). Many forest botanists and soil scientists will be familiar with these approaches to identifying the riparian extent.

Active Channel Determination

Active channel width is the horizontal distance between the lowest extent of continuous perennial vegetation on either side of the stream minus the width of islands (vegetated bars) occurring along the transect. The lowest extent of perennial vegetation may correspond to the boundary of the active channel (see Sigafoos 1964) or the scour line (see Lisle 1986) or the greenline (see Winward 2000) and is typically lower (closer to the channel) than bankfull flow (Leopold and Maddock 1953).

Once the upstream end of a sample reach has been identified, active channel width is determined by measuring the distance between the lowest extent of continuous perennial vegetation on either side of the stream channel. It is not necessary to be meticulously precise in determining the lowest extent of perennial vegetation and representative stream width. Active channel width will vary among transects within a single reach, so the active channel width is measured where the first transect is established at the upstream end of the reach and crosses the channel. Channel width is measured perpendicular to the banks, which may be at an angle to the cross-valley transect (fig. 1; fig. A1.1).

Transect Layout for Channel and Vegetation Measurement

The sampling layout along a reach consists of systematically spaced transects that extend from riparian edge to riparian edge across the valley bottom (including the stream) and are oriented perpendicular to the valley bottom centerline (Appendix 1; Appendix 2). Location of the farthest upstream transect is chosen randomly, ensuring that any distance downstream from the initial point has an equal probability of being selected for a transect location. The distance downstream from the upstream end of the reach is drawn from a random number table (distance measured in meters; Appendix 4). Random number tables may also be found in statistics textbooks or random numbers may be generated with statistical software, spreadsheets, or calculators. Such random-systematic sampling is preferred because it assures that any possible transect location along the reach has equal probability of being selected, assures independence of samples, reduces sampling bias, and satisfies the assumptions of many inferential statistical tests. This allows for reach-level summarizations of central tendency (mean, mode, and median) and variability of biotic and physical characteristics.

A down valley distance of 20 times the active channel width is measured, either in the office using GIS, or in the field with tape, or by pacing parallel to the valley orientation. When the valley centerline is clipped to the stream segment, it can be used to estimate field placement and compass bearing of the first random transect and ensuing transects prior to fieldwork. Once in the field, the upstream and downstream extent of the reach is temporarily marked with flagging along the lowest extent of perennial vegetation/active channel. This is done along both sides of the stream to form a line perpendicular to the valley centerline as determined by compass. The bearing and declination should be

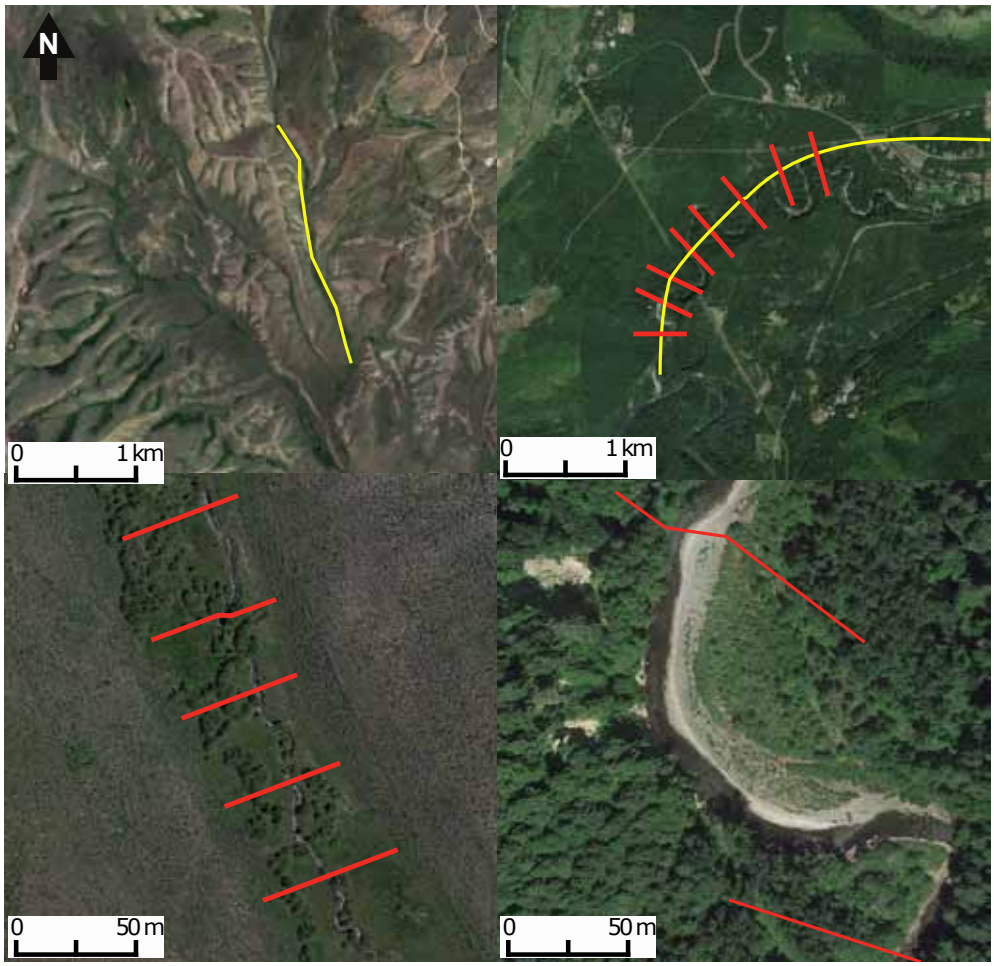

Figure 1—Example of mapping valley trend and transect placements prior to field work. A moderate energy confined valley with a narrow-straight stream planform (Basin Creek, UT; left panels) and a low-energy floodplain with a meandering stream planform (Mashel River, WA; right panels). Yellow lines identify the valley trend longitudinally moving down valley along the stream segment of interest. Red lines reflect vegetation transect placement based on shifting valley trend and are not to scale.

recorded. This bearing will change according to the longitudinal change in the valley centerline that was delineated in the office.

Once the centerline distance and the desired number of transects are determined, the randomly selected starting distance of the first transect is subtracted from the reach length. The result is then divided by the desired number of transects minus one to derive distance between transects. For narrower valleys, transects should be more numerous and spaced more closely (e.g., eight transects). For wider valleys, there should be fewer transects that are spaced further apart (e.g., five transects). The number of transects to be sampled is based on reach physical heterogeneity and the required sample size to detect changes in measured attributes (if they occur). The number of transects should also be proportional to the length of the reach. The number of transects and number of points along each transect should be sufficient to capture variability in the attributes being measured within a reach (Appendix 5); more transects should be established along more heterogeneous and/or longer reaches.

Orientation of transects perpendicular to the valley centerline and the active channel may be important for some projects. The strongest hydrologic gradient along streams is

often a lateral elevation gradient above the channel. This environmental gradient is correlated with flood frequency and flow duration as well as substrate texture, shear stress, depth to water table, and other factors related to fluvial processes and water availability. Riparian plant community organization is influenced by moisture/water availability gradients and magnitude and frequency of fluvial disturbance (Auble et al. 2005; Cooper et al. 1999), which are functions of distance from and elevation above the channel, as well as extra-channel sources of moisture such as local groundwater, seeps, springs, and variability in soil moisture holding capacity.

Transects oriented perpendicular to the channel are useful for evaluating channel cross-sectional form over time. Changes in width, depth, and channel shape may provide an indication of channel degradation or recovery. Interpreting which processes are driving or are driven by vegetation change over time can be more clearly ascertained by measuring riparian vegetation along transects that are also linked directly to channel form, hydrologic, and fluvial processes. Once current vegetation patterns across the valley bottom have been statistically linked to past and present hydrology, including flood frequency, inundation duration, depth to water table, and so on, predictions of shifts in response to physical and hydrologic alteration may be possible (Auble et al. 1994, 2005; Merritt et al. 2010; Rains et al. 2004).

When the valley and active channel are not parallel, place pins (rebar) on either side of the active channel, perpendicular to the stream channel, and then extend valley transects perpendicular to the valley from these cross-sectional anchor points (figs. 1, 2). For general characterization of riparian vegetation in a valley bottom, orientation of transects perpendicular to the valley walls/valley trend is advisable. This approach may be particularly useful when a reach is sampled that has multiple beaver ponds, oxbow lakes, side channels, or tortuous meanders that would otherwise cause transects to cross when overlain on the valley floor.

Transect endpoints may be permanently marked at the edge of the riparian zone on both sides of the stream and monumented for future measurement visits. This can be done by installing rebar end pins, labeling transects with a naming convention, surveying the rebar monuments into a known coordinate system, and recording coordinates and azimuth on metal tags or caps that are affixed to the rebar. All information should be added to geospatial databases for GIS analysis and archiving. Tagline (e.g., Kevlar, nylon, or steel line) and meter tape are extended between transect endpoints horizontally to the ground (using a line level).

In particularly complex riparian areas, a distance meter and level may be necessary to obtain horizontal distance from river left endpoint (facing downstream) to the point or plot being measured. In certain circumstances, sampling across the entire valley is impractical or impossible. In these cases, judgment should be made to determine a reasonable alternative to sampling the entire valley bottom. Examples of this might be to define a near channel zone of some distance on either side of the stream (e.g., two or four times active channel width) to sample, or limiting the work to one side of a stream that might be unsafe or uncrossable.

Ideally, transects should extend across the entire riparian area, so that transect endpoints define the riparian width. Transect endpoints are identified by the transition of riparian surfaces to surfaces dominated by upland vegetation, a distinct change in elevation, or contact with a bedrock valley wall or similar geologic feature. Criteria (rule sets) for determining

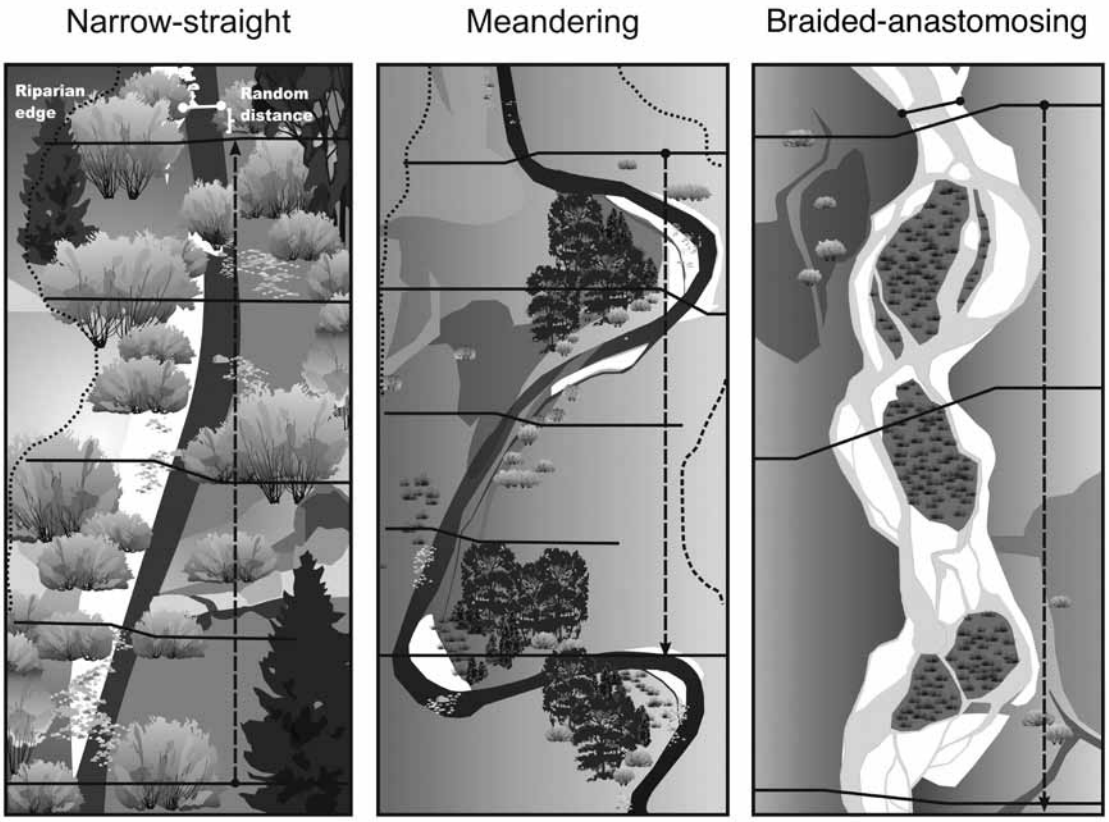

Figure 2—Example stream reaches showing random-systematic placement of transects for straight (e.g., cascade, pool-riffle, step-pool stream), sinuous or meandering, and braided or anastomosing (braided with vegetation on braid bars) stream channel forms. Active channel width is determined at the upstream extent of the reach. The reach length is defined as 20 times the active channel width (shown at top of each frame). The first transect location is determined by selecting a random distance between 1 and 10 meters from the upstream origin of the reach. Transect intervals are determined by subtracting the random distance from the transect length and dividing the resulting length by 4 (5 transects minus 1). For projects that also examine channel change and relationships between riparian vegetation and fluvial processes, transects are positioned to be perpendicular with both the valley and the stream channel. This is accomplished by inserting a transect perpendicular to the stream channel across the stream and 0.5 channel widths on either side of the active channel and then angling perpendicular to the valley walls from the channel transect endpoints.

the transition from riparian to upland (the riparian edge) are presented in Chapter 2 of the Riparian Technical Guide (Merritt et al. In preparation). The National Riparian Protocol Technical Team developed these guidelines using the aforementioned substrate, biotic, and hydrologic criteria for delineating riparian zones. When possible, delineations of riparian edge should be conducted by an experienced riparian ecologist or crew leader.

At sites in which a riparian width cannot be determined with the field criteria indicated above, riparian width should be sampled according to valley type (table 2). As an absolute minimum, transects should be two to four times active channel width on either side of the stream.

Point Layout and Vegetation Sampling Along Transects

The first sampling point is positioned along each transect by pacing or measuring to the first distance along the measuring tape or tagline from the river left endpoint. Subsequent sample points are taken at equal distances along the transect until the transect has been completed (fig. 3).

Table 2—Default minimum sampling width in cases when riparian edge cannot be identified. The transect should be centered over the centerline of the stream channel. Valley bottom types conform to the Hydrogeomorphic Valley Classification (HGVC; Carlson 2009).

Valley bottom type	Riparian transect length (m)
Headwaters	6
High-energy coupled	10
High-energy open	30
Gorge	20
Canyon	20
Moderate-energy confined	20
Moderate-energy unconfined	50
Glacial trough	40
Low-energy floodplain	70

Vegetation Sampling

Many methods can be used to sample riparian vegetation, including plots, transects, belts, and relevés. We examined and considered the pros and cons of each of these methods. However, to maintain objectivity and ease of reproducibility, the vegetation methods described in this guide are the plotless line-point intercept (Scott and Reynolds 2007) and

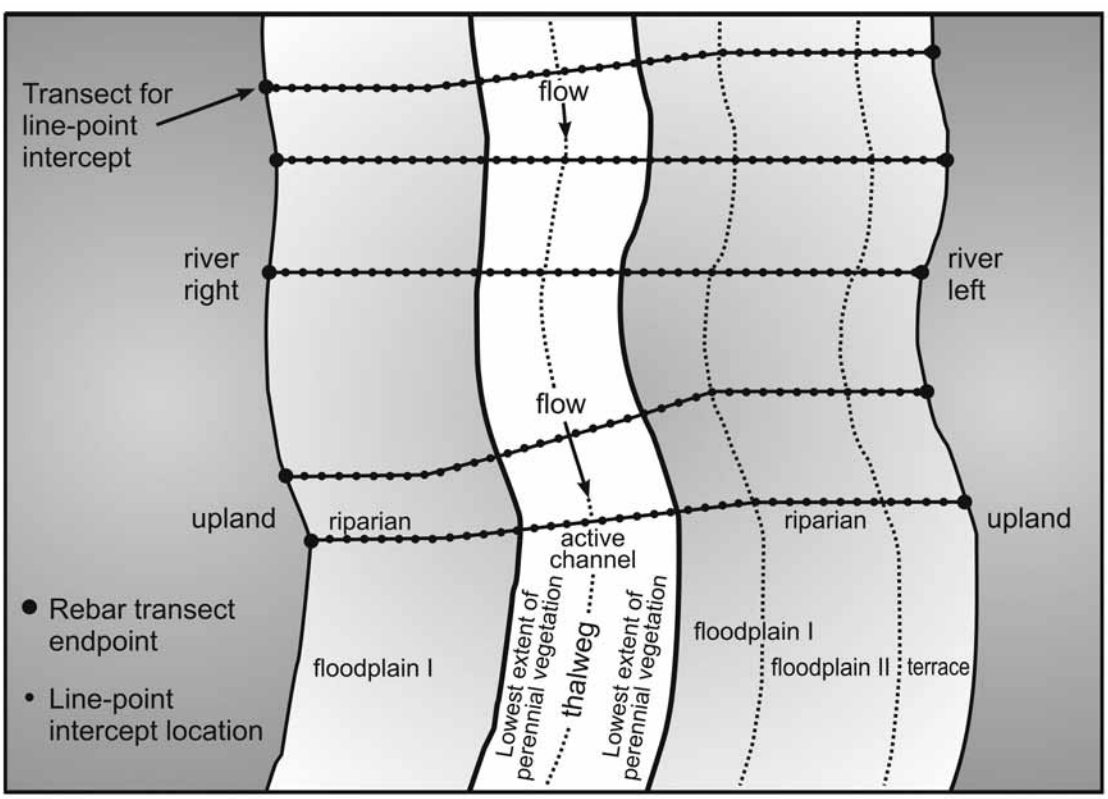

Figure 3—Transects laid out across a valley with points for line-point intercept sampling. Using the line-point intercept method, vegetation intersecting a vertical line at each sampling point is recorded.

point-centered quarter methods (Mitchell 2015). The advantage of using plotless methods as opposed to plot-based techniques is that they are more efficient. Mitchell (2015, p.1) noted that "plotless methods are faster, require less equipment, and may require fewer workers."

Prior to systematically sampling, the field crew should walk the sample reach, identifying as many species that occur within the larger sampling area as possible, and create a species list.

Woody and Herbaceous Vegetation

Presence of all vascular plants is recorded at regular intervals along each transect with the line-point intercept (LPI) method. The LPI method uses either a densitometer, pin flag (or other sharp pointing device), or laser to aid in determining the presence of plant species that occur at points along transects (fig. 4; Appendix 2; Appendix 3). Point intercept sampling is very efficient and highly repeatable relative to cover estimates in plots/quadrats and line-intercept transects (Dethier et al. 1993). LPI precision is about the same among plot and line-intercept sampling, but point sampling takes about 50 to 60 percent less time (Floyd and Anderson 1987; Heady et al. 1959). However, depending on the heterogeneity, fewer species may be recorded with LPI compared to single plot or multiple quadrat sampling of vegetation cover (Elzinga et al. 2001). This can be remedied by sampling more points, including intercept points at more frequent intervals along transects (Chapter 6, Riparian Technical Guide (Merritt et al. In preparation)).

The densitometer (or laser) is typically positioned at a comfortable height for viewing vegetation and aimed downward for lower vegetation layers and upward for upper vegetation layers (as in fig. 4, right frame). For lower canopies, the first species viewed ("intercepted" by the laser) is recorded as a "hit" or presence of that species. Vegetation is moved out of the way after each hit, exposing higher or lower vegetation strata and new species. This may be difficult for overstory vegetation layers. A stadia rod or extended painter's pole may be used to move overstory vegetation layers once they have been recorded to expose upper layers, as would be done for visual estimates of foliar cover in plot-based methods. When the canopy cannot be moved to expose another layer but the laser would otherwise intercept more upward vegetation strata, use judgment to determine canopy layers that should be included in the vertical line of sight. A single species

Figure 4—Densitometer (left two panels) and laser sampling device (panel 3) for measuring presence of vegetation along a vertical line at each point along transects (panel 4).

Table 3—Ground cover types to be recorded at each sample point. The last hit should be classified into one of the following ground cover types.

Physical	Organic
Bare soil—sand (<0.1mm) (BARE1)	Basal vegetation (list plant code on the form) (BAVE)
Bare soil—clay silt (0.1–2mm) (BARE2)	Bryophyte—Cryptograms, mosses and lichens (CML)
Gravel (>2–75 mm) (GRAV)	Wood (WOOD)
Cobble (75–250 mm) (COBB)	Litter: including leaf, needle litter, and other dead plant material or animal droppings (LITT)
Boulder (>600 mm) (BOUL)	
Bedrock (BEDR)	
Water (WATE)	

can be recorded three times at one point as one "hit" per layer. Record the height of each vegetation hit (presence) as one of the following layer class categories (modified from Stromberg et al. 2006):

(1) low vegetation (<1.5 m),

(2) mid-story vegetation (1.5–5 m), and

(3) canopy (>5 m).

If an objective of monitoring is to characterize wildlife habitat complexity, thermal properties of riparian vegetation, or other objectives associated with canopy layering or complexity, additional vertical layer categories may be added. This is repeated until the ground cover is reached, and a ground cover category, which includes basal vegetation, is recorded (table 3). Only one ground cover type should be recorded for each point and should be the first ground cover type encountered after the last live vegetation hit is recorded. Maximum height of the vegetation at each point along the line should also be recorded. This may be done with a distance meter (range finder), or trigonometric calculations using measurements of distance and angle.

Tree Stem Density, Basal Area, and Condition

Individual tree and shrub density, basal area, frequency, and condition may be assessed at points along the transects using the point-centered quarter method (Mitchell 2015; Mueller-Dombois and Ellenberg 2002). This is a quick and effective plotless method in which the sampling interval and number of points sampled will vary from site to site depending on tree (and shrub) density. At a minimum, 20 points are required per reach; these points must be located at consistently spaced intervals along the transects. The transect line and a line cast perpendicular to the transect define the four quadrants. Sites with high tree density will require more point-centered quarter points than sites with fewer trees. At the first point along the transect, the nearest tree in each of four quadrants is identified and the distance to that tree from the point is measured (fig. 5). No tree should be measured at a distance of half the spacing between points (fig. 5).

Tree stem density, basal area, frequency, importance and condition may be assessed by measuring the diameter of stems of each species at breast height (~1.4 m above the

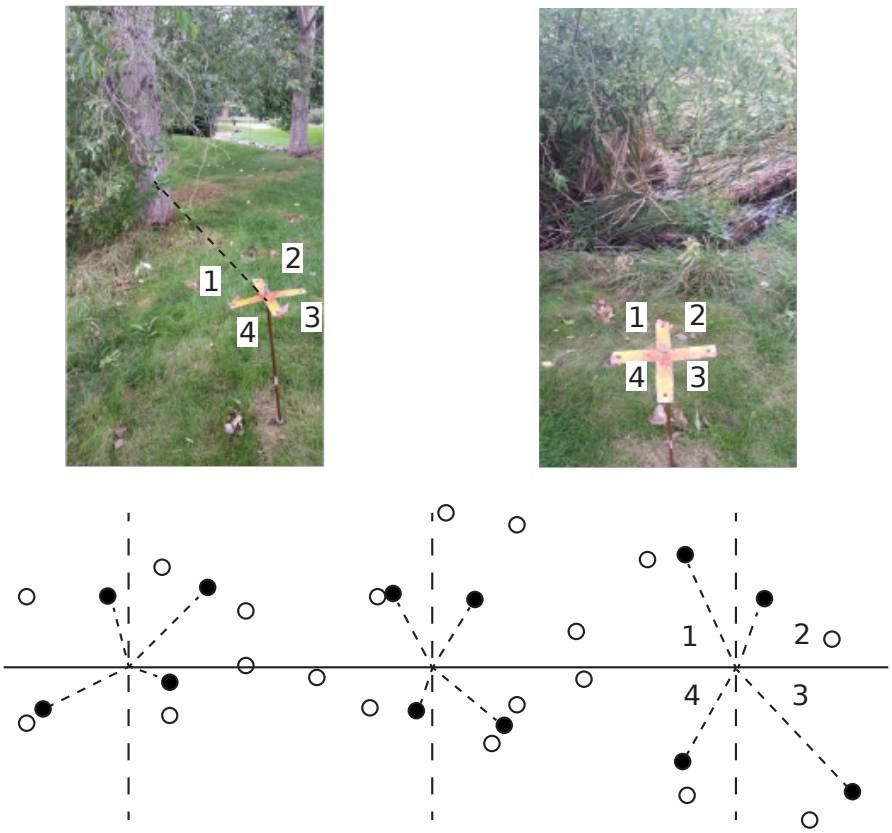

Figure 5—Point-centered quarter frame (top panel) and four quadrants for sampling tree density, basal area, and canopy condition. The layout of the frame at vegetation sampling points (solid circles) along transects varies as a function of tree (open circles) density. The nearest tree in each quadrant is identified to species, the stem diameter at breast height is measured, and vigor class identified. Sampling points must be at equal intervals along the transect for a site. Sampling points along the transect must be far enough apart that the same tree is not sampled in two adjacent sampling points. Point-centered quarter sampling points at each of the filled circles in the figure would have resulted in double sampling some trees, so the sampling points were taken at every other point. Lower frame reproduced from Mitchell (2007).

ground). Diameter tapes or calipers may be used to measure trunk and stem diameters. Basal area, stem density, and frequency by species calculations are described in Mueller-Dombois and Ellenberg (2002).

Tree health can be assessed visually through an evaluation of canopy condition compared to estimated full canopy—hereafter, vigor class (table 4). Water stress, disease, fire, insect infestation, shading, competition, browsing, nutrient deficiency, or soil toxicity may lead to leaf wilting, leaf discoloration or damage, partial or complete leaf death, and branch dieback (Larcher 2003). Vigor class should be recorded for each tree or shrub that is measured in each of four quadrants using the point-centered quarter method.

Potential canopy should be estimated as a visual determination of percentage of live canopy relative to potential crown volume (Scott et al. 1999) for all woody individuals. The proportion of a tree's potential canopy, also called canopy vigor, is estimated by visualizing a full canopy as defined by branching patterns, and then estimating and recording the percentage of that entire area that is foliated (fig. 6). The condition (vigor) of that canopy is then considered using table 4 and a vigor class assigned at a precision of +/–5 percent.

Crown dieback has been associated with increased mortality risk in riparian trees (Scott et al. 1999; Tyree et al. 1994). Percent of potential canopy can be used to assess

Table 4—Categories of vigor (canopy condition) for trees. Assessed only for trees measured using the point centered quarter method. Leaf stress may be caused by water stress, disease, insects, or fire.

Vigor	Criteria for assessing condition
Critically stressed	Major leaf death and or branch die back (>50% of canopy volume affected)
Significantly stressed	Prominent leaf death and or branch die back (21–50% of canopy volume affected)
Stressed	Minimal leaf death and or branch die back (11–20% of canopy volume affected)
Mildly stressed	Little or no sign of leaf stress (between 5%–10% of canopy affected)
Vigorous	No sign of leaf stress/very healthy looking canopy (<5% of canopy affected)

damage caused by water stress associated with leaf death and abscission, water stress and cavitation, branch die back, disease, insect infestation, herbivory, branch fall, fire, and other causes (Scott et al. 1999). If possible, the cause of diminished vigor should be recorded: WS, water stress; PD, pathogens or disease; MD, mechanical damage such as wind, falling branches, or human canopy removal; I, insects; or UK, unknown/other.

Plant Specimen Collection

Specimens should be collected for all unknown species that are recorded at points in the LPI samples. If fewer than 20 individuals are present at a site, do not collect the plant, as it may be locally rare. Instead, describe the plant, the setting in which it occurs, and take a photograph. Also, be mindful of any rare local and regionally rare species that should not be collected under any circumstances.

The entire plant (including roots, flowers, fruits, and seeds) should be collected and pressed in a plant press for herbaceous species. Branches, leaves, flowers and fruits of woody species should be collected when possible. Note the habit of each species (e.g., caespitose/clumped, rhizomatous, annual, and perennial). Labels should be attached to the collection so identification can be traced back to the specific unknown on the field data form. Guidelines for the collection, preparation, and preservation of plant specimens are available online (https://www.amnh.org/explore/curriculum-collections/biodiversity-counts/plant-identification/how-to-press-and-preserve-plants/, and others). An experienced botanist should identify unknown specimens.

Physical Feature Measurement

Geomorphic Classification of Fluvial Surfaces

Transects are walked end to end to determine obvious breaks in geomorphic surfaces, and distances of these breaks from river left endpoint are recorded. Surfaces along the transect should be classified as active channel, mid channel bar, lateral bar, island, bank, floodplain I, floodplain II…floodplain *n*, terrace I, terrace II… terrace *n*, colluvial surface, or transitional (Knighton 1998; fig. 7). Not all fluvial features are expected to be found along a particular transect or reach. The active channel is the length between the lowest extent of riparian vegetation on either side of the channel minus islands. Bars are

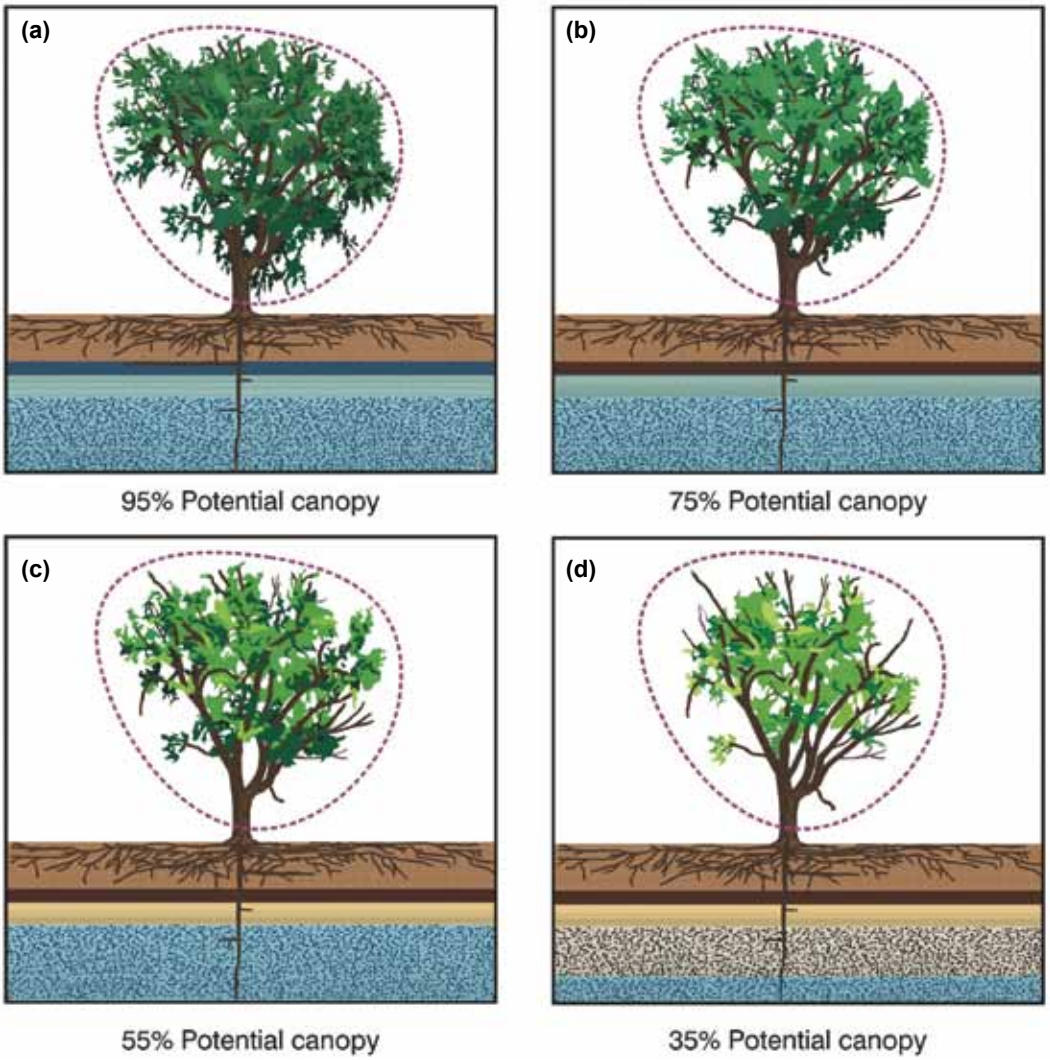

Figure 6—Estimating percent potential canopy and placing canopies into condition scale. Percent potential canopy is estimated by visualizing a full canopy as defined by branching patterns (dotted line), and then estimating and recording the percentage of that entire area that is foliated. Individuals are (a) mildly stressed, (b) significantly stressed, (c) significantly stressed, and (d) critically stressed. If possible, the cause of diminished vigor should be recorded: WS—water stress, PD—pathogens or disease, MD—mechanical damage (such as wind, falling branches, or human canopy removal), I—insects, or UK—unknown/other.

typically bare depositional features, which may be partially vegetated, within the active channel and at an elevation above water stage when the active channel is full. Islands are vegetated bars (use same ecoregion-specific percent cover criteria as for determining lowest extent of perennial vegetation; Chapter 2 Riparian Technical Guide, (Merritt et al. In preparation)). Banks are the first obvious break in topography along channel margins. Channel shelves are seasonally inundated surfaces just above the bank but not extensive enough to be considered floodplain.

Floodplains are gradually sloping depositional surfaces that are inundated fairly frequently (1–5 year recurrence intervals). Terraces are abandoned former floodplains that are rarely inundated. Floodplain I, floodplain II, etc., and terrace I, terrace II, etc., may be distinguished from one another by an obvious break in topography (transition; fig. 7). Colluvial surfaces (e.g., talus slopes, colluvial fans) may be dominant along streams in

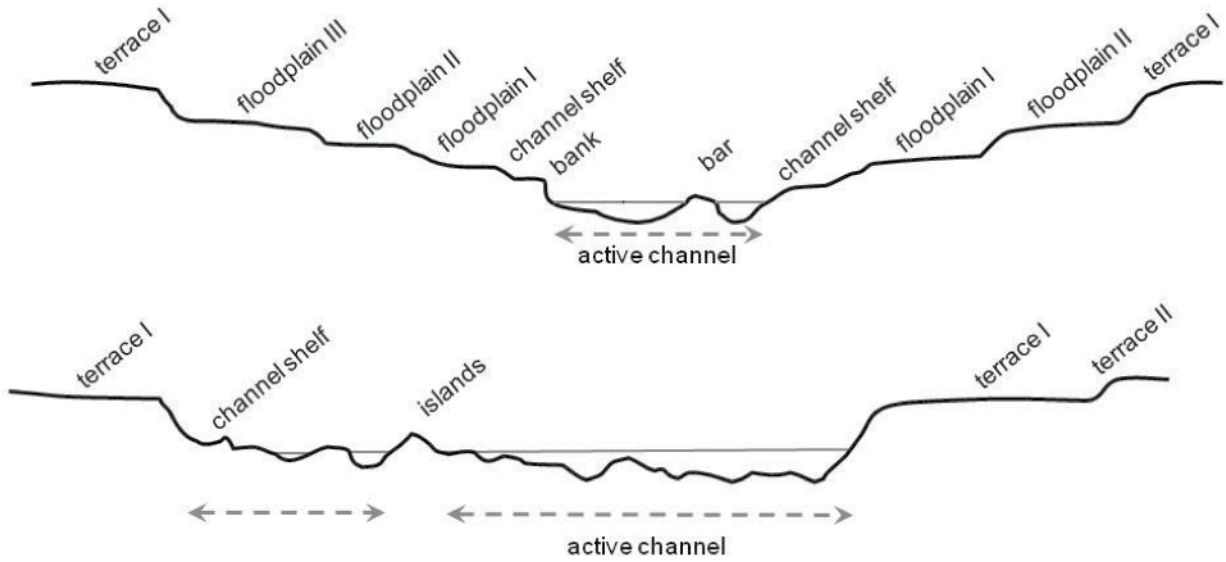

Figure 7—Idealized channel cross-sections showing active channel, islands and bars, channel shelf, floodplains, terraces, and transitions. Meandering or straight stream in top frame; braided stream in lower frame. Islands are in channel features that are vegetated; bars are non-vegetated to partially vegetated and part of the active channel. Active channel in the lower frame—a braided channel—is the sum of the three active channels.

confined canyons and mountainous headwaters, and they may consist of surfaces in the riparian area that were deposited from side slopes. More detailed classification of fluvial features may be desired in some studies. Examples of subclasses of floodplain and bank and channel features are provided in table 5.

Active Channel Width

Active channel width should be measured at intervals of one channel width from the upstream to downstream ends of the reach (10–20 points along reach). Active channel width is the horizontal distance perpendicular to the channel centerline between the lowest extent of perennial vegetation on either side of the stream.

Channel Cross-Sections

When possible, each transect is surveyed as a cross-section of the bed, bank, and floodplain landform elevations with a rod and level, total station, laser level, or Real Time Kinematic (RTK) satellite-based positioning systems from the permanent marker on river left riparian edge to the permanent marker on river right (rebar installed at the edge of the riparian zone). If rod and level or other survey tools are not available, use of a stadia rod to measure distance to the ground surface from a tight, leveled tag line is acceptable but not preferred. Another acceptable method of surveying a cross section is to use a hand level and stadia rod (https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs141p2_023906.pdf). Between surveyed vegetation points, the distance along the tape and elevation are recorded at every major break in topography following the guidelines of Harrelson et al. (1994). Record the start and stop distance of each of the classified fluvial features along the cross section. Along each transect, position of active channel boundaries, lowest extent of perennial vegetation on islands, and water's edge

Table 5—Floodplain, channel, and bank features that should be noted as an attribute of vegetation sampling points along each transect.

Primary category	Secondary category
Channel features	Gravel or sand bar on margin of the active channel
	Gravel or sand bar in the active channel
	Active channel (includes flowing water and area scoured by flowing water)
	Island (vegetated or not; includes mid-channel vegetated bars or log jams)
	Gravel or sand deposit next to stream, which appears to be outside the active channel
Bank features	Channel shelf—transition from aquatic to terrestrial (includes streambank)
	Steep cutbank
	Hillslope (toeslope, midslope, or upper slope)
Floodplain features	Depression or abandoned channel
	Backwater slough
	Oxbow lake Beaver pond
	Outer edge of riparian area (e.g., inactive terraces with transitional riparian/upland vegetation)

should be surveyed. The active channel should be surveyed perpendicular to the channel orientation.

Reach Longitudinal Profile

Longitudinal profiles of the bed and water surface of the entire reach are surveyed along the channel centerline (refer to Harrelson et al. 1994). Points along the thalweg, defined as the deepest part of the channel, are measured at intervals of one channel width through the entire reach in addition to points at major breaks in bed profile. The longitudinal profile may be plotted in the field using graph paper or spreadsheet software to assure that the reach is uniform with no major breaks in slope.

In cases where surveying cross-sections is impractical or impossible for field crews, active channel width should be recorded at each transect through the reach. Some streams may present difficulties in taking many of the measurements outlined above. Beaver ponds, braiding, multiple channels, or natural lakes create complexities in transect layout. Keeping the transect perpendicular to the outer most extent of perennial vegetation is advised. Suggestions for such cases are given in Appendix 6.

Data Entry, Quality Control and Assurance, and Analysis Techniques

Data entry, quality control and assurance, and data summary and analysis techniques are detailed in Chapter 8 of the Riparian Technical Guide, (Merritt et al. In preparation). Additional information on analysis may be found in Mueller-Dombois and

Ellenberg (2002) and Elzinga et al. (2001). This section only briefly introduces a range of analytical options.

Having taken the core set of measurements outlined above, many site attributes may be quantitatively summarized, including: species composition, richness and biodiversity, non-native species abundance, proportions of various plant functional groups, frequency/abundance of individual species, total basal area of trees, density and size-class structure of trees by species, vertical structure of vegetation, habitat heterogeneity, channel form, channel width to depth ratio, channel gradient, etc. These measures can be used to track changes in important site attributes over time or to compare multiple sites to one another. Reaches along a segment may be used to track large-scale changes in a stream segment over time. Sites may be evaluated and compared using a variety of metrics and summary statistics (Riparian Technical Guide, Chapter 6; Merritt et al. In preparation).

In addition to the data provided by the core protocol, the basic framework may be augmented to meet specific study objectives. Table A7.1 in Appendix 7 provides examples of attributes that should be added to the core protocol for changes to riparian areas that involve: (1) hydrologic alteration, (2) physical changes to channels, or (3) vegetation removal. The hydrologic alteration add-on is recommended for projects that aim to document vegetation and channel changes due to altered surface, soil, and/or groundwater availability. Dam-caused flow alterations, water diversions, groundwater pumping, climate change, land-use change causing shifts in snowmelt or runoff patterns, and other causes of altered water availability and seasonal distributions of flows can be assessed using the hydrological alteration add-ons to the core protocol.

Adding physical alteration metrics to the core protocol is appropriate for measuring the effects of altered sediment delivery to the valley bottom or stream channel (increases, decreases, or changes in sediment properties) or other causes of direct alteration to channel morphology. Outdoor recreational use, wildlife or livestock impacts to streambanks, mechanical alteration from machinery, and other direct impacts to channels can be quantified using the physical alteration add-ons to the core protocol.

Finally, questions regarding livestock and wildlife grazing and/or browsing, riparian forestry practices, mowing or hay cutting, agriculture, wildfire, or any other activities that physically remove vegetation biomass can be addressed through the vegetation disturbance add-ons to the core protocol. Regardless of the application to which the riparian protocol is applied, it is recommended that the core attributes (Appendix 7) be measured and tailored to project objectives.

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Appendix 1—Overview of Valley Determination and Reach Location Workflow to Guide Field Sampling

Valley Assessment and Reach Location

This protocol includes additional GIS layers to illustrate valley bottom mapping, valley trend (centerline) identification, and transect placement on each of the representative HGVC channel types. These are available as a part of the National Riparian Protocol group at https://usfs.maps.arcgis.com/home/index.html.

Table A1.1—Valley assessment and reach location.

Task 1: Identify valley bottom extent, type, and trend for overlaying sampling design

Step	Description	Reference
1	Identify the valley extent using GIS data: topography, valley bottom mapping software, hydrogeomorphic valley class outputs (HGVC), or other valley class and size information.	pg. 3
2	Identify the valley trend in GIS and overlay a valley centerline over the stream segment of interest. This centerline should follow the valley center and be parallel to the valley margins.	pgs. 4–5
3	Use GIS to overlay perpendicular transects over the centerline at each reach within a stream segment. Identify segments and reaches with exceptions (beaver ponds, oxbows, etc.) Save transect coordinates and transect heading for location in the field.	pgs. 4–5
4	Locate transect ends and survey in the field locations, which may differ from those identified in the office. Save transect endpoint coordinates for attribution within GIS.	pgs. 6–7

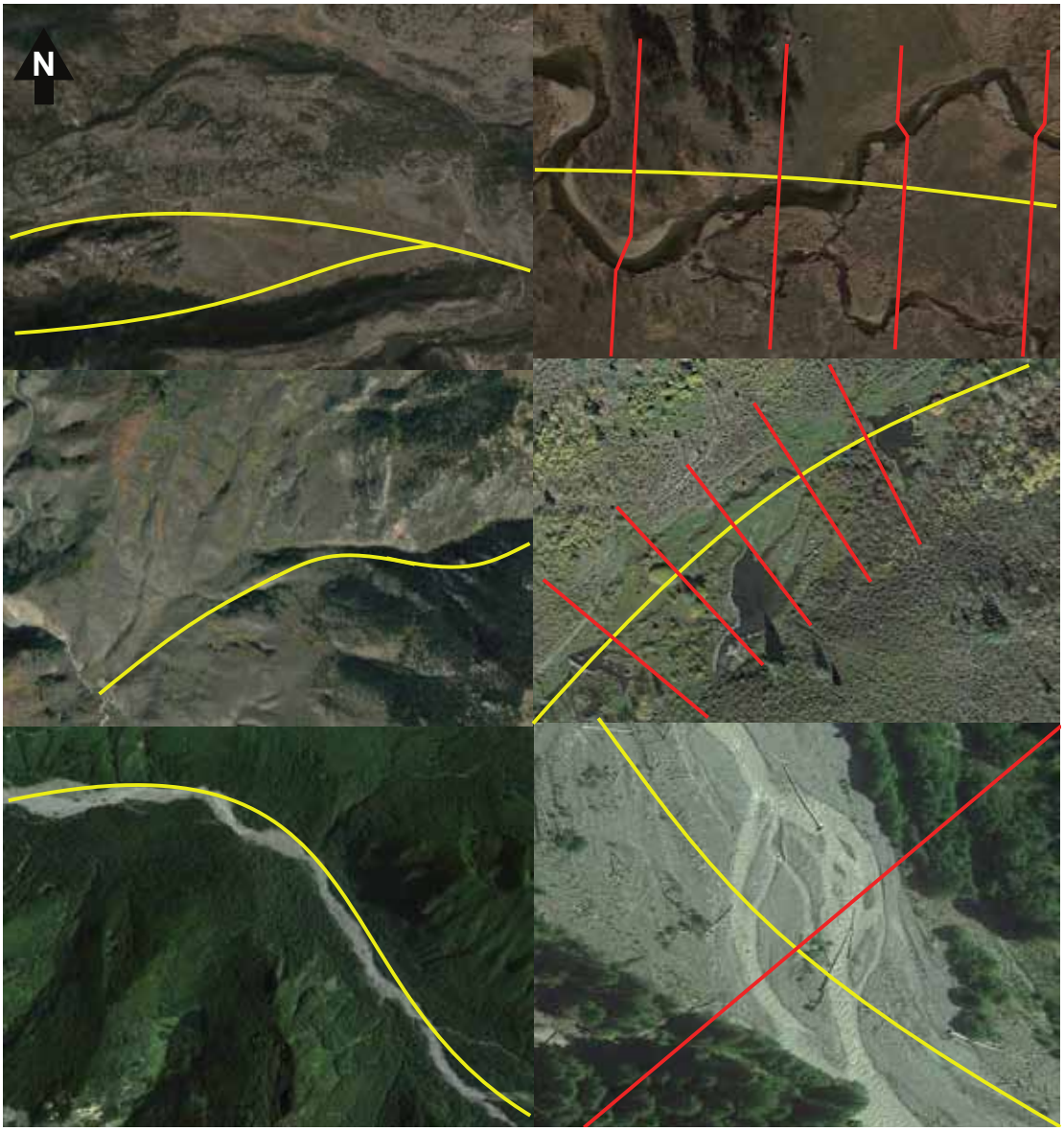

Figure A1.1— Examples of valley trendlines mapped using GIS (yellow lines) and transect layout (red lines) based on valley trend and channel orientation.

Appendix 2—Field Sampling at a Glance

Table A2.1—Reach vegetation sampling.

<table>
<tr><th colspan="2">Task 1: Measure presence of woody and herbaceous vegetation</th><th></th></tr>
<tr><th>Step</th><th>Description</th><th>Reference</th></tr>
<tr><td>1</td><td>Starting from a random point along the transect, record presence of woody and herbaceous vegetation at regular intervals. To measure vegetation, aim the densitometer or laser upwards or downwards as appropriate. Record the first species viewed or “hit” with the laser. Move this layer of vegetation out of the way and continue recording “hits” until ground cover or the limit of upper canopy is reached.</td><td>pgs. 7–10</td></tr>
<tr><td>2</td><td>If data on vertical vegetation structure are required, record the height of the vegetation as one of the following categories: Low Vegetation (<1 m), Mid-story Vegetation (1–5 m), Canopy (>5 m). Note that the presence of a species is recorded only once per height class.</td><td>pgs. 11–12</td></tr>
<tr><td>3</td><td>Ground cover is recorded only once, following the last vegetation “hit” in the down direction that is recorded. Groundcover categories are:
<table>
<tr><th>Physical</th><th>Organic</th></tr>
<tr><td>Bare soil (soil particles <2 mm)</td><td>Bryophyte</td></tr>
<tr><td>Basal vegetation</td><td>Wood <10cm</td></tr>
<tr><td>Gravel (2–64 mm)</td><td>Wood >10cm</td></tr>
<tr><td>Cobble (65–256 mm)</td><td rowspan="4">Litter: leaf, needle litter, other dead plant material, animal scat, etc.</td></tr>
<tr><td>Boulder (>256 mm)</td></tr>
<tr><td>Bedrock</td></tr>
<tr><td>Water</td></tr>
</table></td><td>pgs. 12–13</td></tr>
<tr><th colspan="3">Task 2: Measure tree stem density, basal area, and condition</th></tr>
<tr><td>1</td><td>Point centered quarter survey transects are established along each transect.</td><td>pgs. 13–14</td></tr>
<tr><td>2</td><td>For the closest tree within each quarter of the point centered quarter frame, measure the diameter at breast height, 1.37 m above the ground. For individuals less than 25 cm tall, measure basal diameter.</td><td>pgs. 13–14</td></tr>
<tr><td>3</td><td>Assess canopy condition of identified trees using the following categories:
<table>
<tr><th>Canopy condition</th><th>Criteria</th></tr>
<tr><td>Critically stressed</td><td>Major leaf death and or branch die back (>50% of canopy volume affected)</td></tr>
<tr><td>Significantly stressed</td><td>Prominent leaf death and/or branch die back (21–50% of canopy volume affected)</td></tr>
<tr><td>Stressed</td><td>Minimal leaf death and or branch die back (11–20% of canopy volume affected)</td></tr>
<tr><td>Mildly stressed</td><td>Little or no sign of leaf water stress/no water stress related leaf death (5–10% of canopy volume affected)</td></tr>
<tr><td>Vigorous</td><td>No sign of leaf water stress/very healthy looking canopy (<5% of canopy volume affected)</td></tr>
</table></td><td>pgs. 14–15; Table 4</td></tr>
<tr><td>4</td><td>Assess potential canopy for each tree species. This is estimated as a visual determination of the percentage of live canopy relative to crown volume.</td><td>pgs. 13–16, Figure 6</td></tr>
<tr><th colspan="3">Task 3: Plant specimen collection</th></tr>
<tr><td>1</td><td>Specimens are collected for all unknown species recorded at points in the LPI samples (see guidance on rare species). The entire plant is collected and pressed in a plant press as soon as possible. Branches, leaves, flowers, and fruits of woody species should be collected when possible. Note the habit of each species (e.g., rhizomatous vs. bunched roots)</td><td>pg. 15</td></tr>
</table>

Table A2.2—Channel measurements.

Task 4: Geomorphic classification of fluvial surfaces		
Step	**Description**	**Reference**
1	Walk transects from end to end to determine obvious breaks in geomorphic surfaces.	pg. 15
2	Classify surfaces along transect as active channel, mid channel bar, lateral bar, island, bank, floodplain I, floodplain II…floodplain n, terrace I, terrace II… terrace n, colluvial surface, or transitional.	pgs. 16–17, Table 5 and Figure 7
Task 5: Determine active channel width		
1	Measure active channel width at intervals of one channel width from the upstream to downstream ends of the reach (10–20 points along reach). Active channel width is the horizontal distance between the lowest extent of perennial vegetation on either side of the stream.	pg. 17
Task 6: Survey channel cross sections		
1	Survey each transect with a rod and level or total station. Between surveyed vegetation points (or plots), record distance along the tape and elevation at every major break in topography.	pg. 17
2	Record start and stop distance of each of the classified fluvial features.	pgs. 17–18
3	Along each transect, survey the position of active channel boundaries, lowest extent of perennial vegetation on islands, and water's edge.	pgs. 17–18
Task 7: Survey longitudinal profile of reach		
1	Survey the longitudinal profiles of the bed and water surface of the entire reach along the channel centerline.	pg. 18
2	Measure points along the thalweg at intervals of one channel width through the entire reach in addition to points at major breaks in bed profile.	pg. 18
3	Plot longitudinal profile in the field to assure that the reach is uniform (no major breaks in slope along the reach).	pg. 18

Appendix 3—Gear List for Line-point Intercept Method

Essential

- Protocol (this document)
- Forms (copies from Appendix 8)
- Clipboard
- Mechanical pencils
- Stakes ("candy canes," range pins, pin flags)
- Flagging
- Compass
- Measuring tools
  - □ Kevlar (or rope) tag line
  - □ Measuring tapes (at least two; 50 m or longer)
  - □ Measuring staff, 1.5 m
  - □ Ruler (approximately 30 cm)
  - □ Densitometer or Laser Point Sampler
  - □ Diameter tape (for DBH)
  - □ Calipers
- Plant collection tools
  - □ Plant press (with cardboard, newspaper, and felt)
  - □ Permanent marker
  - □ Sample bags and plant tags
  - □ Digging tool

Optional

- Electronic data recorder, if available
- Plant identification tools
  - □ Local species list
  - □ Flora, keys, plant ID books, etc.
  - □ Hand lens (10x or combination lenses)
  - □ Plant press, newspaper or blotter, permanent marker
- Laser rangefinder or sonic distance meter
- GPS unit
- Camera (spare memory and batteries)
  - □ Photographic scale
  - □ Board or card for identifying photo location
- Notebook (waterproof)
- Topographic map of site
- Aerial photograph of site
- Calculator

Appendix 4—Random Numbers for Determining Initial Transect Location

First transect should be *x* distance downstream from the beginning of the reach.

5	6	1	5	6	7	1	1	3	10	4	10	8	10	7	8	2	7
9	2	6	7	5	3	10	1	10	3	5	3	1	8	8	10	9	3
9	6	7	10	7	8	1	6	8	3	3	2	2	8	7	4	8	4
5	4	5	8	1	5	2	3	3	10	1	8	9	6	8	4	5	7
1	8	4	2	7	2	7	5	8	2	4	7	5	9	2	4	3	8
4	1	5	10	4	7	6	1	3	6	8	7	7	5	4	1	4	9
7	5	5	5	2	7	7	8	5	5	1	6	3	4	2	9	10	9
2	5	8	7	9	9	10	1	2	6	2	5	7	1	1	8	9	8
5	10	10	4	8	7	1	6	4	9	9	9	2	1	6	1	2	6
4	6	5	10	2	6	9	5	6	3	9	8	4	6	4	8	3	9
10	10	7	7	3	5	10	10	4	5	9	4	7	2	9	6	4	7
9	3	9	1	6	4	7	1	3	9	2	7	9	10	8	3	8	10
8	9	3	9	5	3	9	4	9	5	10	7	7	2	2	1	5	8
9	4	8	7	3	2	10	7	6	10	3	4	6	1	3	6	8	7
7	2	4	7	4	7	5	3	6	3	3	7	4	4	1	4	2	2
10	6	5	1	7	9	1	8	8	1	3	5	1	8	3	7	1	3
8	1	4	1	2	1	10	8	9	2	8	3	1	5	7	9	6	4
9	6	6	4	9	6	7	8	7	8	8	5	3	1	7	2	10	6
1	10	5	8	2	1	5	10	3	5	10	7	4	10	4	9	7	8
3	3	1	1	5	3	8	4	1	1	5	9	5	3	6	8	7	4
7	2	9	2	1	1	3	7	6	9	7	6	7	1	10	3	7	4
4	5	3	10	9	2	2	5	9	1	10	2	8	7	10	10	7	2
4	3	8	10	7	2	6	5	4	3	6	7	5	5	8	8	2	10
5	1	2	2	2	8	5	7	3	9	2	6	1	7	6	4	3	7
3	9	6	8	4	2	1	3	4	7	3	7	6	4	3	8	6	8
5	4	6	7	3	2	10	2	9	1	10	2	2	3	1	6	3	6
3	3	2	7	5	9	7	8	6	8	8	10	7	3	7	2	7	1
4	4	2	6	6	5	5	4	4	6	1	3	7	10	6	3	1	8
2	10	4	7	9	1	5	10	9	10	2	2	9	8	8	4	3	3
9	7	3	10	9	5	10	6	8	4	6	1	3	2	9	10	8	8
5	4	1	6	6	3	10	9	1	7	1	1	6	6	1	4	8	3
4	10	5	6	7	6	6	10	4	4	5	3	1	1	9	10	9	2
10	2	8	8	6	5	7	7	7	5	3	8	6	4	10	6	8	9
7	10	3	9	5	3	10	7	4	9	7	2	10	5	7	3	3	9
7	6	4	3	2	1	9	10	10	4	8	6	2	2	1	1	1	1
8	3	5	4	3	6	5	3	4	10	2	1	3	3	2	9	6	4
3	1	2	1	3	4	2	1	4	5	1	1	9	2	5	9	2	6

Appendix 5—Determination of Number of Points at a Site and Along a Transect

Methods for determining necessary sample size for detecting change in a particular variable at a given level of confidence are outlined in Elzinga et al. (2001) and Legendre and Legendre (1998) and include species accumulation curves, plotting running means of variables, and power analysis. If species richness is a variable of interest, a species-area curve could be fitted to species data in the plots and an adequate number of plots determined by the asymptote of the curve (fig. A5.1). In a similar way, the mean or variance of a variable of interest could be plotted as a function of number of points (fig. A5.1). The number of transects may also vary depending on the variables of interest, the objectives of the monitoring, and time and resources available.

If the mean and variance of an attribute can be estimated (from other studies or a pilot study), the number of plots necessary to estimate the true mean of the attribute at a particular confidence level can be estimated using power analysis (methods outlined in any statistics text; examples provided in Platts et al. 1987; also see James-Pirri et al. 2007).

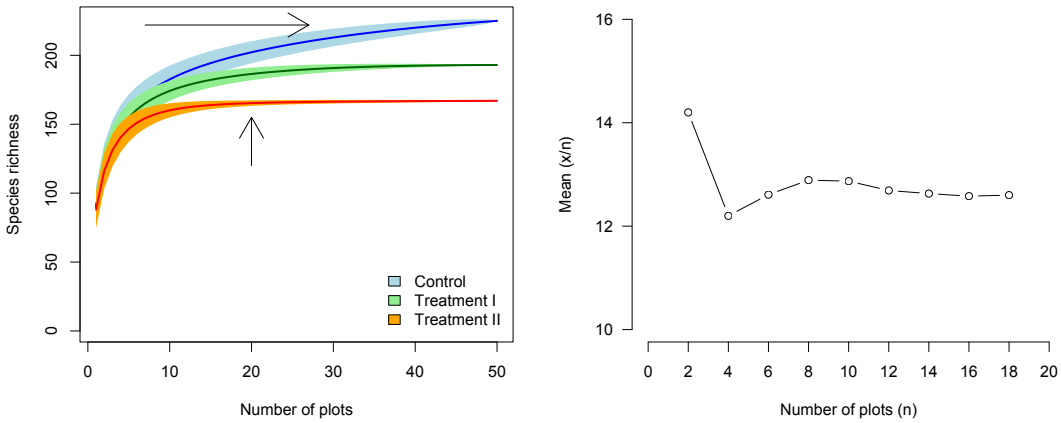

Figure A5.1—Examples of methods for determining adequate numbers of points (or plots) to establish at sites based upon different measurement objectives: (a) species accumulation curves with arrows indicating asymptote and adequate number of samples to estimate species richness along a control and study reach; (b) plot of running mean of a variable of interest (x) indicating that 8–10 plots are adequate (based on Mueller-Dombois and Ellenberg 2002).

Appendix 6—Special Cases

Some riparian areas are not conducive to the site layout described in the text. For beaver ponds, heavily braided or anastomosing streams, and streams without a defined channel, it is recommended that the following modified site layout be used.

The reach length could be modified to encompass the area occupied by the special case, such as the beaver pond (i.e., the area upstream of a beaver dam that is influenced by the dam). It is useful to identify upstream and downstream boundaries of the special case if they exist. If there are no such boundaries, then a default reach distance of 100 m is recommended. If there are distinct areas of the special case (e.g., beaver pond, zone of braided stream) then it is recommended that each zone be sampled separately. For example, if there is a repeating pattern of beaver ponds interspersed by defined stream segments, it is recommended that each beaver pond be sampled as a distinct special case and that the defined stream reach be sampled with the core riparian protocol (unless that area is very short relative to the overall length sampled). If the beaver pond area is relatively small (perhaps less than 30 percent of valley length) then the beaver pond could be included in a larger reach sampled with the riparian protocol. If there are relatively short (perhaps less than 30 percent of valley length) defined stream reaches between beaver ponds, those short reaches could be included in the special case sampling.

To sample the special case, identify a straight line down the middle of the valley. Establish transects at systematic intervals as described above (based on reach length) perpendicular to the line running up and down the valley. Extend each transect from one edge of the valley bottom to the other, rather than using a set transect length. These types of sites (beaver ponds, braided streams, etc.) will often fill much, if not all, of the valley bottom. Therefore, it is desirable to sample the entire area. Collect data as described in the Groundwater-Dependent Ecosystems (GDE) technical guide protocol (USDA Forest Service 2012). If it is not feasible to sample the entire valley bottom, use a set transect length (refer to table 1 in main text).

Springs: Use the GDE protocol, which includes sampling of the spring and 20 m of the spring creek. The rest of the spring creek beyond 20 m of the spring could be sufficiently sampled with the core riparian protocol and not as a special case.

Wetlands near streams: Wetlands that are adjacent to streams could be sampled as part of the riparian site or independently with the GDE protocol. If there is interest in soil characteristics water table dynamics, the GDE protocol is recommended. Below are some additional recommendations for deciding which protocol to use.

- Spring or wetland in floodplain: Riparian protocol is recommended. Include as part of a riparian site associated with a stream.
- Spring or wetland on terrace/bench or hillslope adjacent to a stream (not in floodplain): GDE protocol is recommended.
- Oxbow lake or pond in the floodplain: If relatively small, it could be included in riparian sampling. If relatively large, it should be sampled independently with the GDE protocol.
- Oxbow lake or pond on terrace/bench: GDE protocol is recommended.

Appendix 7—Objective-Based Add-Ons to the Core Riparian Protocol

Table A.7.1—Additional monitoring attributes and their relationship to key monitoring questions.

Category	Sub-category	Attribute to measure	Hydrologic alteration	Physical alteration	Vegetation alteration	Core
Vegetation	Presence, abundance and size	Presence/frequency of plant species	X	X	X	X
		Life form	X	X	X	X
		Tree size and density	X	X	X	X
		Channel shading		X		
		Invasive species			X	
		Canopy closure			X	
		Extent (width) of riparian area	X	X	X	X
	Condition	Leaf stress	X	X	X	X
		Live crown ratio	X			
		Crown transparency			X	
		Shrub mortality			X	
		Snags and defective trees			X	
		Browse and grazing utilization			X	
Soil and ground surface	Ground cover Soil/ subsurface	Bulk density		X		
		Infiltration rate		X	X	
		Platy structure		X		
		Soil characteristics		X		
		Root abundance in soil			X	
		Water table level		X	X	
		Surface displacement		X		
		Ground cover	X	X	X	X
		Coarse wood			X	
Streambank	Bank characteristics	Bank angle		X		
		Overhanging streambanks		X		
		Composition of bank		X		
	Bank disturbance	Tracks/trails on streambank		X		
		Bank instability		X	X	
Channel	Dimensions of channel	Channel longitudinal profile	X			
		Channel pattern	X			
		Channel cross-section	X	X		

Appendix 8—Vegetation Data Field Forms

Riparian Core Protocol Data Form: Line Point Intercept

Study_____Date_____Examiner(s)_____
Reach_____

Transect	Distance From Left Pin in __(unit)	Ground Cover	Species (Height <1.5m)	Species (Height 1.5 to 5 m)	Species (Height >5 m)	Fluvial Setting

Key:

Ground Cover: Si: bare silt or clay, Sa: bare sand, G: gravel, P: pebble, C: cobble, BL: boulder, BR: bedrock, H20: water, BV: basal vegetation, BY, bryophyte W: wood, L: litter.

Fluvial Setting: CH: channel, B: bank, FP1: floodplain 1, FP2: floodplain 2, T1: terrace 1, T2: terrace 2, *i*: Island, BC: back channel, TR: transition, UP: upland. ETC if other

Riparian Core Protocol Data Form: Trees

Study_____Date_____Examiner(s)_____
Reach_____

Transect:	Distance From Left Pin in __(unit)	Species Name	Tree Diameter ___(unit)	Dist. From Quadrat ___(unit)	Canopy Condition Class to the 5%

Condition Class Key

C: critically stressed (>50% of canopy affected), SS: significantly stressed (21-50%), S: stressed (11-20%), MS: mildly stressed (5-10%), V: vigorous (<5% or less of canopy affected)

Geomorphic Analysis of Transect Worksheet

Study_____Date_____Examiner(s)_____
Reach_____ Transect #:_____

Feature	Distance	Elevation

Notes:

Geomorphological Analysis of Transect Worksheet

Study_____Date_____Examiner(s)_____
Reach_____ Transect #:_____

Feature	Distance	Elevation

Notes:

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