# U.S.D.A. Forest Service
# National Riparian Vegetation Monitoring Core Protocol: Conterminous U.S.



Prepared by
The U.S.D.A. Forest Service
National Riparian Technical Team
2014 DRAFT

**Table of Contents**

**Objectives**

The purpose of this document is to provide guidance on measuring riparian vegetation and channel characteristics along wadeable stream channels[1], floodplains, and valley bottoms. This protocol is designed to guide the user in gathering data to assess riparian plant species composition and channel conditions at the reach scale, to compare species composition and conditions to other reaches at a point in time or the same reach through time, and to provide a basic framework for riparian vegetation monitoring that can be built upon to address specific management objectives. This core protocol can be used to collect basic information on riparian areas, with the intent of characterization, and/or as a baseline for additional sampling as part of long-term monitoring. However, 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, determining the effects of vegetation removal, etc. are provided in Chapter 2 of the U.S.D.A. Forest Service Riparian Monitoring Protocol Technical Guide (hereafter Riparian Technical Guide). These objective-based, add-on measures are also summarized in Appendix 5 of this document.

Riparian areas are often highly physically heterogeneous, biologically diverse, and may have high rates of species turnover through time relative to surrounding uplands. The dynamic nature of stream channels makes sampling, monitoring, and evaluating conditions of riparian areas challenging. Many methods have been developed for measuring and assessing conditions in riparian areas for a given stream type and a set of objectives (e.g., Platts et al 1987, Prichard et al. 1993, Winward 2000, Coles-Ritchie 2002, Peck et al. 2003, Burton et al. 2007). Such methods are often adequate for achieving the specific goals and stream channel types for which they were designed. There is no 'ideal' or 'best' protocol for every setting and every purpose.

[1] Defined as first through third order streams in Peck et al. (2003).

Monitoring plans tailored to meet clearly defined objectives and a defined scale, scope, and area of interest are preferred. This core protocol is designed to measure important characteristics of riparian areas which include: species composition, vertical structure of vegetation, size-class structure of trees, and physical channel characteristics.

The methods outlined below are intended for use on a wide variety of stream types and valley settings. Flexibility is deliberately built into this protocol, and it is necessary for the user to tailor the methods to specific sites, settings, conditions, and project objectives. The number of transects, sampling techniques, number of point samples, spacing of transects, points, and specific methodologies may need to be modified for specific projects. Each step in the protocol is summarized in Appendix 1, and a list of gear necessary to collect data in the field is presented in Appendix 2.

These approaches presume that the following assumptions are met:

- Monitoring design, data collection, analyses, and interpretation are supervised by a qualified riparian plant ecologist;
- The sampling reach has been selected prior to field data collection using field reconnaissance, aerial photographs, and/or maps;
- The sampling reach is comprised of a distinct and continuous valley type/setting and stream type;
- The sampling reach is not located within or immediately downstream from a tributary junction;
- The sampling reach will be sampled repeatedly through time. Reach endpoints permanently marked with rebar are preferable. As will be discussed below,

repeated random (probabilistic) sampling of a reach is advised if the channel is dynamic;

- Other factors influencing plant species composition (confounding factors) such as grazing, mechanical disturbance, fire, etc. have been recognized and accounted for in data analysis and interpretation.

**Site Selection and Reach Determination**

Valley type (determined by slope, width, form, and geology) exerts constraints on the range of stream channel forms that may occur along a stream segment, which in turn constrains the physical characteristics and the potential riparian vegetation at a site. Carlson (2009) identified nine valley types for the western U.S. in the Geomorphic Valley Classification (GVC), including: 1) headwaters, 2) high-energy coupled, 3) high-energy open, 4) gorge, 5) canyon, 6) moderate-energy confined, 7) moderate-energy unconfined, 8) glacial, and 9) low-energy floodplain (refer to the Riparian Protocol Technical Guide). Sampling layout, number and length of transects, and certain measurements may vary by valley type (Frissel et al. 1986, Poole et al. 1997)[2]. An initial classification of valley types is important so that replicate reaches along a segment are of similar valley form and that control or reference segments are of a similar valley type compared to impacted segments. The GVC tool and instructions for its use are housed at the Remote Sensing Applications Laboratory in Salt Lake City, UT (see http://www.landscapetoolbox.org/). If classification of valley types using the GVC is not possible, valley width and valley slope measured from quadrangle maps may be used to define valley types for comparison. Furthermore, other valley classifications may be used to stratify sampling design (e.g., Rosgen Valley Classification; Rosgen 1996).

*Identifying Stream Segments and Reaches*

For the purposes of this protocol, a *reach* is defined as a 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) and is a convenient and

[2] See Riparian Monitoring Technical Guide Chapter 2 for a description of the Geomorphic Valley Classification (GVC) and descriptions of channel forms.

logical unit for riparian vegetation and channel monitoring. The reach should encompass several sequences of repeating channel forms (e.g., pool-riffle, step-pool, or meanders/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 and so that segments may be compared.

A valley *segment* is the length of stream of interest and is typically several-to-many stream reaches in length (Bisson et al. 2006). A valley segment may be the portion of stream located upstream or downstream from a point of impact (e.g., dam, diversion, or grazing allotment), a length of stream between tributary junctions, a length of stream of similar valley and channel form, or any portion of a stream consisting of multiple reaches that is to be sampled and *to which inference is to be made*. Stratifying segments into different valley types and choosing reaches of a uniform channel form are important in controlling for variability within segments and reaches so that changes in the variables of interest are detectable. In most cases, comparisons among segment types should be within similar valley types.

Reach locations along a valley segment of interest should be determined through randomly choosing an initial point along the valley centerline of the segment and: 1) systematically choosing a downstream interval for sampling reaches (e.g., every 0.5 km) or 2) subjectively sampling representative channel types along the segment. Subjective sampling is limiting in that conclusions are made only about the condition of the vegetation sampled (at points), not the entire reach. If randomly or systematically selected reaches encompass more than one valley type or a significant change in channel characteristics, reaches should be relocated upstream or downstream until a uniform reach is located.

Segment and reach locations may be identified in the office prior to field work. Up- and downstream extent of segments should be identified on contour maps, GIS coverages of hydrography, or aerial imagery. Digital orthogonal aerial imagery, such as that available from the National Agricultural Imagery Program (NAIP)[3] or Google Earth, are useful for identifying the upper and lower extent of valley segments, determining the orientation of the valley centerline, systematically or randomly locating stream reaches within a segment, determining channel dimensions, and roughly delineating riparian boundaries.

A subset of the total number (population) of possible reaches along a segment is selected for sampling, and each selected reach is a *sampling unit*. A minimum of three reaches is recommended for representing a segment. Multiple transects are established along each reach. The number of transects established along a reach, and number of plots or points along each transect, may vary as a function of the objectives of the project and statistical considerations (Appendix 4). A total of five transects and 200 points per reach are recommended as a minimum; more points are preferable. Distances between points should not exceed 5 m. Along wide valleys, this may result in a number of sample points far greater than 200, so longer sampling times are required  for larger valley bottoms. For analysis and comparison among reaches, the sampled points along a particular transect and occurring on a particular fluvial surface (e.g., floodplain, bank, terrace, or island) is the statistical unit. The subsampled presence absence data from each point are pooled by reach and all reach level data are pooled by fluvial surface (or other meaningful unit for comparison).

The intensity of sampling might be less for riparian characterization compared to a project involving litigation or hypothesis testing in an experimental design. The intensity of sampling and optimal allocation of effort between subsampling reaches and sampling more

[3] http://www.apfo.usda.gov/FSA/apfoapp?area=home&subject=prog&topic=nai

reaches will also be constrained by: 1) heterogeneity in channel form and vegetative attributes (e.g., presence, cover, density, frequency), 2) achieving an adequate sample size (with the reach as the sample unit) to detect change in some variable of interest, or 3) factors such as available resources and site accessibility.

The goal in choosing the number of reaches, transects, and sampling intervals is to obtain a sample size that provides information for addressing issues of interest while not oversampling and expending unnecessary time, resources, and effort. If there is variation within a segment that is not necessarily of interest for monitoring (e.g., changes in channel form, fence line contrasts, or some other confounding reason for vegetation change), it is advisable that a single reach not straddle the two impact zones (e.g., grazed and ungrazed).

Data should be gathered systematically across the entire valley bottom (not weighted or altered to specifically over- or under-sample fluvial surfaces). The dataset will be stratified during analysis after field work is complete.

*Riparian Area Determination*

The edge of a riparian area is determined using three criteria as outlined in Chapter 2 of the Riparian Technical Guide. The edge of the riparian area corresponds to: 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 3) *hydrologic attributes* -- the area of the valley bottom flooded at the stage (water surface elevation) of the 100 year recurrence interval flow.

*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 (i.e., closer to the channel) than *bankfull flow* (Leopold and Maddock 1953).

Once the upstream end of a sampling 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, established at the upstream end of the reach, crosses the channel. Channel width is measured perpendicular to the banks (which may be at an angle to the cross-valley transect).



**Transect Layout for Channel and Vegetation Measurement**

The sampling layout along a reach consists of a number 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. Location of the upstream most transect is randomly chosen, ensuring that any distance downstream from the initial point has an equal probability of being selected for a transect location. A distance in meter increments downstream from the upstream end of the reach is drawn from a random number table

(Appendix 3). Random number tables may also be found in a statistics text or random numbers may be generated in the office or field using statistical software, spreadsheet[4], or calculator. Such random-systematic sampling is preferred as it assures that any possible transect location along the reach has equal probability of being selected, assures independence in selected samples, reduces bias in sampling, and satisfies the assumptions of many inferential statistical tests. This allows for reach-level summarizations of central tendency (e.g., mean, mode and median) as well as variability of biotic and physical characteristics along the reach.

A down valley distance 20 times the active channel width is measured with tape or by pacing parallel to the valley orientation. The upstream and downstream extent of the reach is temporarily marked with flagging along the lowest extent of perennial vegetation/active channel along both sides of the stream to form a line perpendicular to the valley centerline as determined by compass (record bearing and account for declination).

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, more transects spaced closer together are advisable (e.g., eight transects); for wider valleys fewer transects spaced further apart is advisable (e.g., five transects). Choice of number of transects is based on the heterogeneity of the reach, the desired sample size for statistical considerations (i.e., sufficient statistical power to detect a change or differences in measured attribute/s if they occur), and be proportional to the length of the reach. The number of



[4] In Microsoft Excel the function =RAND()*100 yields a (pseudo; with replacement) random number between 0 and 100. The multiplier value may be changed to the maximum length of the reach to be sampled. The function =RANDBETWEEN(0,x) returns a random number between 0 and whatever value is inserted for x. Random numbers should be rounded off to the nearest whole number (in meters).

transects should be sufficient to capture the variability in the attributes being measured within a reach; 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 gradients/water availability and magnitude and frequency of fluvial disturbance, 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 in evaluating channel cross-sectional form through time. Changes in width and or depth and channel shape may provide an indication of degradation or recovery. Interpretations of the processes driving or driven by changes in vegetation patterns through time will be more clearly ascertained through having riparian vegetation measured in such a way that it can be directly linked to channel form, hydrologic, and fluvial processes. Once current vegetation patterns across the valley bottom have been statistically linked to past and present hydrology (flood frequency, inundation duration, depth to water table, etc.), predictions of shifts in response to alterations in physical variables (e.g., hydrology) may be possible (Auble et al. 1994, Rains et al. 2004, Auble et al. 2005).

When the valley and active channel are not parallel (e.g., deviate in orientation by more than 10 degrees), and hydrologic linkages are of interest, the valley wide cross sections should be kept perpendicular to the valley walls, but a short cross section perpendicular to and encompassing the active channel and one-half a channel width on either side should be added (Figure 1). For general characterization of riparian vegetation in a valley bottom, orientation of transects perpendicular to the valley walls or valley trend is advisable.

We suggest that endpoints of each transect be permanently marked at the edge of the riparian zone on either side of the stream with rebar, labeled, and coordinates (e.g., Universal Transverse Mercator (UTM) or Latitude-Longitude) and azimuth (angle from North corrected for declination) recorded. Tagline (e.g., kevlar, nylon, or steel line) and meter tape are extended between transect endpoints horizontally to the ground (using a line level, available in hardware stores). In very 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 such 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., 2 or 4 times active channel width) to sample, or limiting the work to one side of a stream that might be impossible to cross.

Ideally, transects should extend across the entire riparian area, so transect endpoints define the riparian area width. Transect endpoints are identified by the transition of surfaces considered riparian 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 the transition from riparian to upland (the riparian edge) are in Chapter 2 of the Riparian Technical Guide. These guidelines were developed by the National Riparian Protocol technical team using the definition of riparian areas and the three criteria for delineating riparian zones[5].



---

[5] A *fluvial riparian area* is one adjacent to a channel with intermittent, interrupted, or perennial flow that exhibits regionally distinctive streamside vegetation (or has the potential to) and signs of fluvial processes and/or fluvial

When possible, delineations of riparian edge should be conducted by an experienced riparian ecologist/crew leader.



features created under the current climatic regime. If other criteria do not apply or cannot be determined, a default minimum riparian sample area should be measured (Table 1).

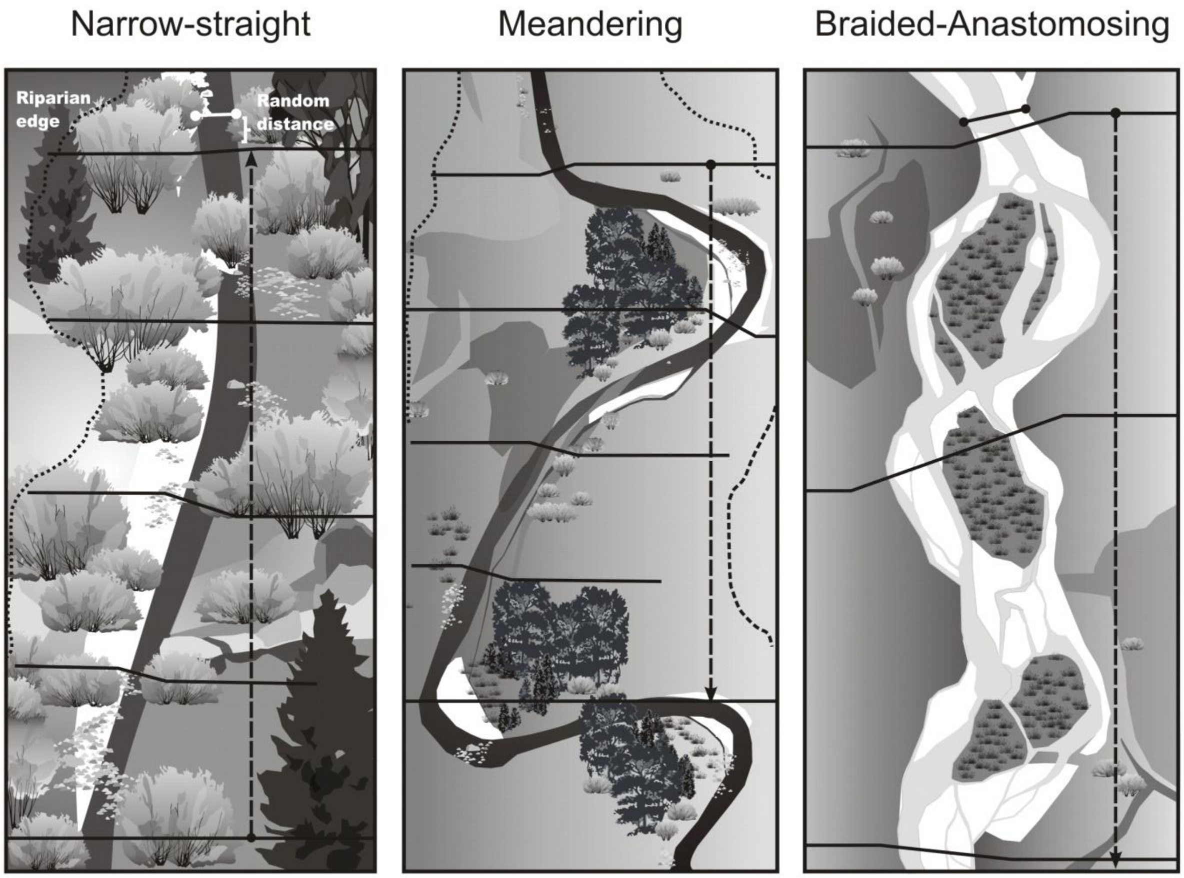


Figure 1. Example stream reaches showing random-systematic placement of transects for straight (e.g., cascade, pool-riffle, step-pool stream), sinuous or meandering, and braided or anastomosing (braided with vegetation on braid bars) stream channel forms. Active channel width is determined at the upstream 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.

At sites in which a riparian width cannot be determined using the field criteria indicated above, riparian width should be sampled according to valley type (Table 1). As an absolute minimum, transects should be 2 to 4 times active channel width on either side of the stream.

Table 1. 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 Geomorphic Valley Classification (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 |

**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, tagline, pacing, or other measurement device from the river left endpoint. Additional sampling points are at equal distances along the transect (Figure 2).

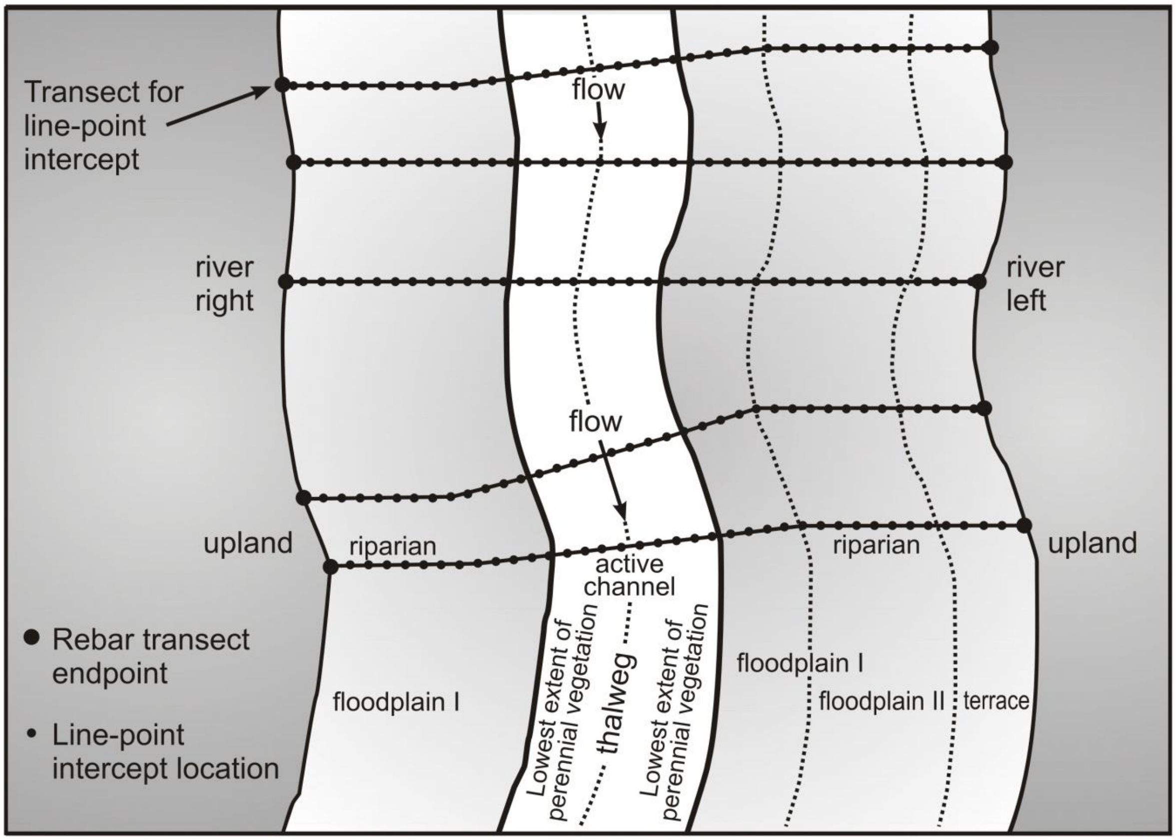


Figure 2. Transects laid out across a valley with points for line-point intercept sampling. Using the line-point intercept method, vegetation intersecting a vertical line at each sampling point is recorded.



**Vegetation Sampling**

Though many plot-based methods are applied to riparian sampling, and we considered many of these methods, vegetation methods described in this guide are plotless: line-point intercept Point centered quarter. The advantage to using plot-less methods as opposed to plot-based techniques is that they are more efficient. “Plot-less methods are faster, require less equipment, and may require fewer workers” (see Mitchell 2007; http://faculty.wwu.edu/wallin/envr442/pdf_files/PCQM.pdf). Alternative methods that would provide similar information to the methods described below include line intercept along the transects (for woody vegetation) and quadrat sampling (in 0.5 x 1 m plots for herbaceous vegetation). These methods have been tested and compared to one another. We found the methods below to be comparable and more efficient than standard plot-based methods.

*Woody and Herbaceous Vegetation*

Presence of woody and herbaceous plants is recorded at regular intervals along each transect using the line-point intersect (LPI) method. The LPI method uses either a densitometer or laser to aid in determining the presence of plant species that occur at points along transects (Figure 3). Point intercept sampling is very efficient and highly repeatable relative to cover estimates in plots/quadrats and line-intercept (Dethier et al. 1993). LPI precision is about the same among plot and line intercept sampling, but point sampling takes about 50% to 60% less time (Heady et al. 1959, Floyd and Anderson 1987). However, depending on the heterogeneity, fewer species may be recorded using LPI compared to single plot or multiple quadrat sampling of vegetation cover (Elzinga et al. 2001). This can be remedied by sampling more points (e.g., points at more frequent intervals along transects; refer to Chapter 6, Riparian Technical Guide).




Figure 3. 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).

The densitometer[6] (or laser[7]) is typically positioned at a comfortable height for viewing vegetation and aimed downward for lower layers of vegetation and upward for upper layers (as in Figure 3, right frame). For lower canopies, the first species viewed (or 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 and new species. This may be difficult for overstory layers of vegetation. A stadia rod may be used to move overstory vegetation layers once they have been recorded to expose upper layers. As with any other method, use judgment to determine canopy layers that would likely be included in the vertical line of sight in cases where the canopy cannot be moved and laser cannot reach. A single species 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: 1) low vegetation (<1m), 2) mid-story vegetation (1-5m), and 3) canopy (>5m) (modified from Stromberg et al. 2006). 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 can be added. This is repeated until the ground cover is reached, and a ground cover category (which includes basal vegetation) is recorded (Table 2). Only one ground cover type should be recorded for each point; the first ground cover type encountered after the last vegetation hit is recorded.



[6] Instructions for using a densitometer may be found at: http://www.grsgis.com/users-guide.html.

[7] Ordering information and instructions for Laser Point Samplers may be obtained at: http://shop.countgrass.com/product.sc;jsessionid=4F3EFCE5684BFAB1CCFBC8B76860494E.qscstrfrnt03?productId=3&categoryId=1

Table 2. 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 |
|---|---|
| | Basal vegetation (list plant code on the form) (BAVE) |
| Bare Soil - sand (<0.1mm) (BARE1) | Bryophyte – Cryptograms, mosses and lichens (CML) |
| Bare Soil - clay silt (0.1-2mm) (BARE2) | Wood (WOOD) |
| Gravel (>2 – 75 mm) (GRAV) | |
| 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) | |

*Tree Stem Density, Basal Area, and Condition*

Tree stem density, basal area, frequency, importance and condition may be assessed at points along the transects using the point centered quarter method (Mueller-Dombois and Ellenberg 2002, Mitchell 2007). This is a quick and effective plotless method, but sampling interval and number of points sampled will vary from site to site depending on tree density. At a minimum, 20 points are required per reach, these points must be located at consistent intervals along the transects. The transect line and a line cast perpendicular to the transect defines 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 (Figure 4).

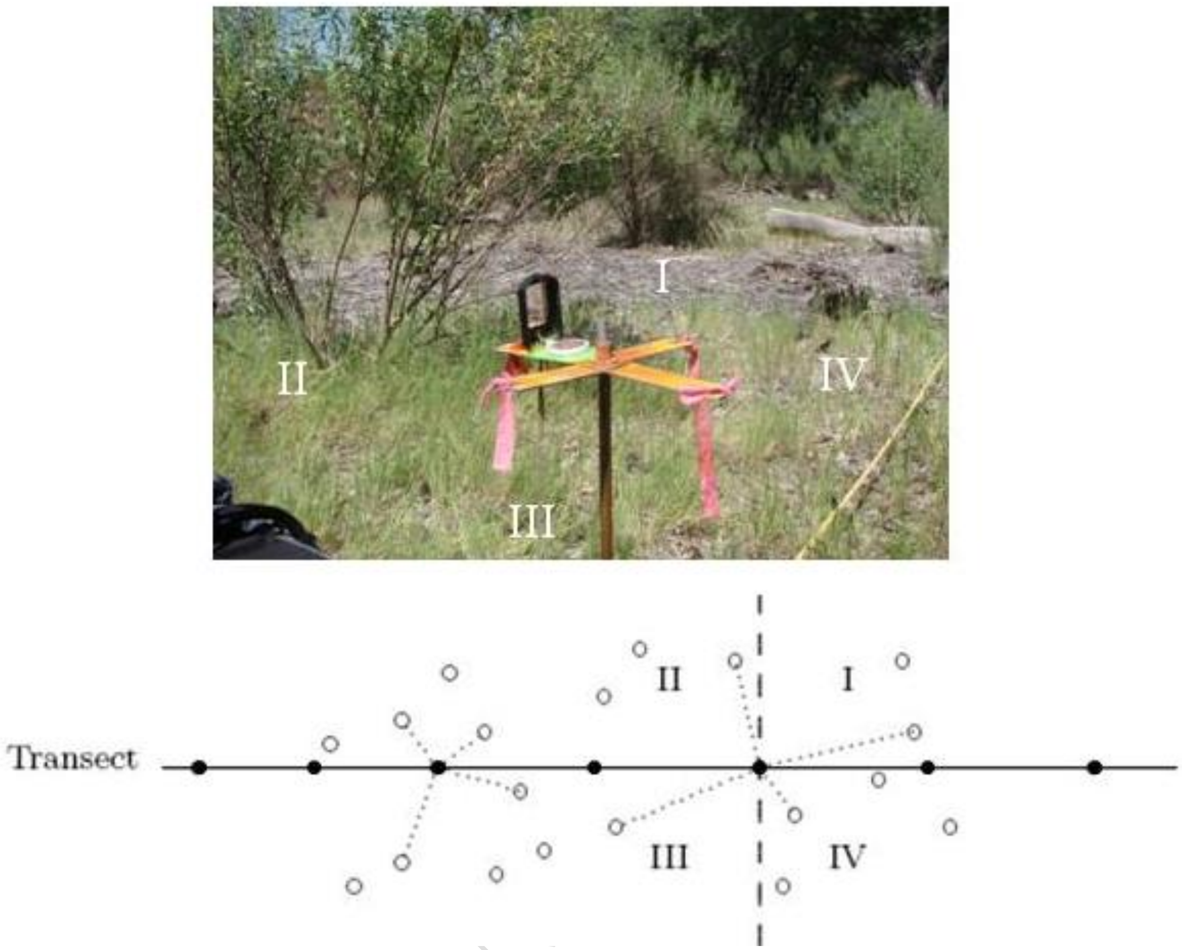


Figure 4. Point centered quarter frame (top panel) and four quadrants for sampling tree density, basal area, and canopy condition. The layout of the frame at vegetation sampling points (solid circles) along transects varies as a function of tree (open circles) density. The nearest tree in each quadrant 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, therefore the sampling points were taken at every other point. Lower frame reproduced from (Mitchell 2007).



Tree stem density, basal area, frequency, importance and condition may be assessed by measuring the diameter of stems of each species at breast height (1.37 m above the ground) Diameter tapes or calipers may be used to measure trunk diameters. Basal area, stem density, and frequency by species calculations are detailed in Mueller-Dombois and Ellenberg 2002 and Mitchell 2007.

Tree health can be assessed visually through an evaluation of canopy condition compared to estimated full canopy – hereafter, vigor class (Table 3). Water stress, disease, insect infestation, etc. may lead to leaf wilting, leaf discoloration, partial or complete leaf death, and branch dieback. Vigor class should be recorded for each tree that is measured in each of four quadrants using the point centered quarter method.

Table 3. Categories of vigor (canopy condition) for trees. Assessed only for trees measured using the point centered quarter method.

| 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) |
| *Normal* | Little or no sign of leaf water stress/no water stress related leaf death (between 5 and 10 percent of canopy affected) |
| *Vigorous* | No sign of leaf water stress/very healthy looking canopy (< 5% of canopy affected) |

Potential canopy should be estimated as a visual determination of percentage of live canopy relative to potential crown volume (i.e., extent of all branches; Scott et al. 1999) for all woody individuals. Percent potential 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 (Figure 5). The condition (vigor) of that canopy is then considered using Table 3 and a vigor class assigned.

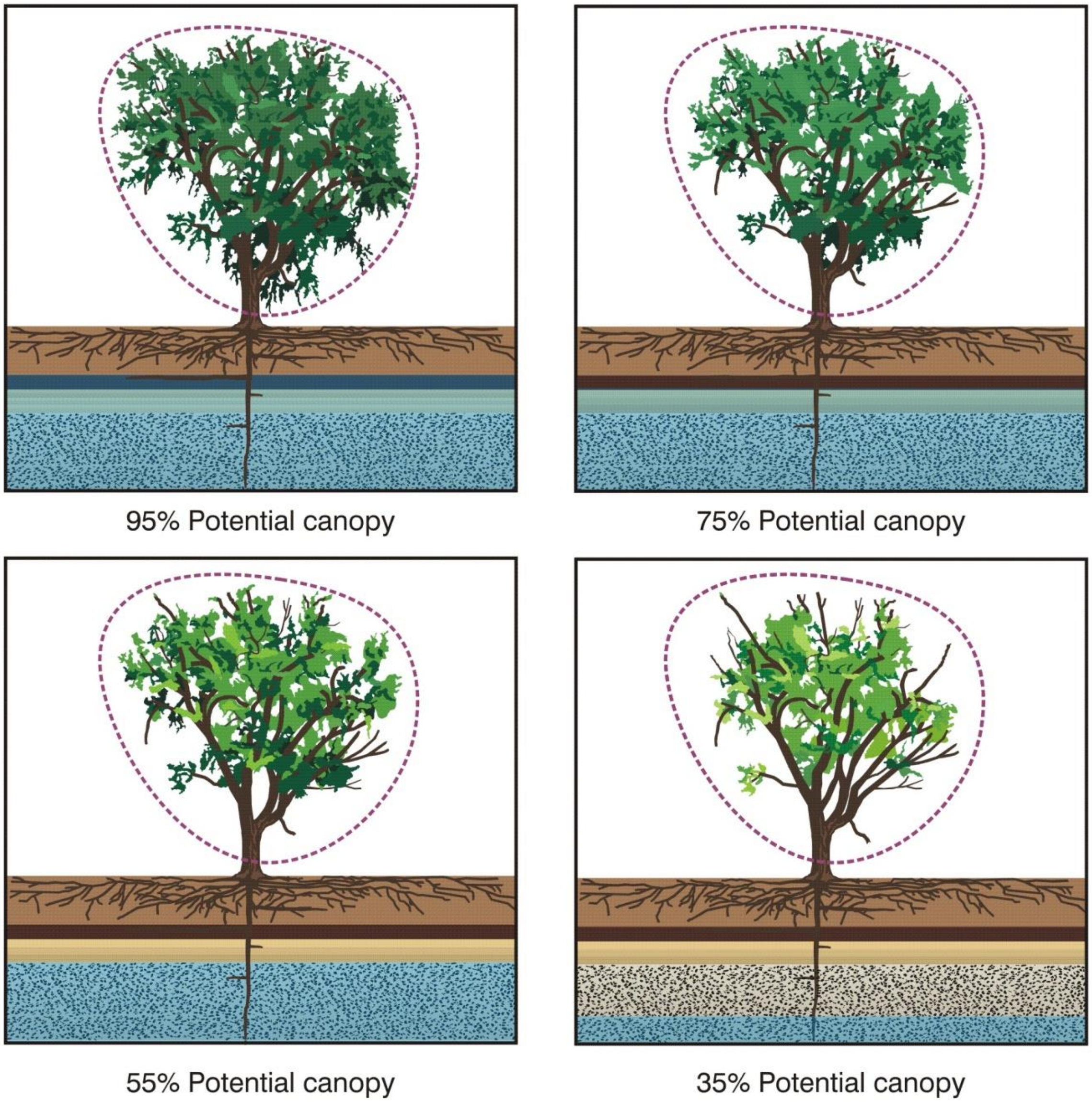


Figure 5. Estimating percent potential canopy and placing canopies into condition scale. Percent potential canopy is estimated by visualizing a full canopy as defined by branching patterns (dotted line), and then estimating and recording the percentage of that entire area that is foliated.  Individuals are vigorous, stressed, critically stressed, and significantly stressed (clockwise from top left).

Crown dieback has also been associated with increased risk of mortality in riparian trees (Scott et al. 1999). Percent of potential canopy can be used to assess damage caused by water stress associated with leaf death and abscission, water stress and cavitation, and branch die back

(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*

It is recommended that specimens be collected for all unknown species recorded at points in the LPI samples. If fewer than 20 individuals are present at a site, do not collect the plant. Instead, describe the plant, the setting, and take a photo. Also, be mindful of any rare local and regional are 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 (http://herbarium.usu.edu/K-12/collecting/specimens and others). These specimens will be identified later by an experienced botanist.



**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 (Figure 5). Not all fluvial features are expected to be found along a particular transect or reach. *Active channel* is the length between lowest extent of riparian vegetation on either side of the channel minus islands. *Bars* are 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). *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; Figure 6). Colluvial surfaces (e.g., talus slopes) may be dominant along streams in confined canyons and headwaters, and 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, bank and channel features are provided in Table 5.

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) |
| Bank features | Gravel or sand deposit next to stream, which appears to be outside the active channel |
| | Channel shelf - transition from aquatic to terrestrial (includes streambank) |
| | Steep cutbank |
| Floodplain features | Hillslope (toeslope, midslope, or upper slope) |
| | Outer edge of riparian area |
| | Depression or abandoned channel |
| | Backwater slough |
| | Oxbow lake |

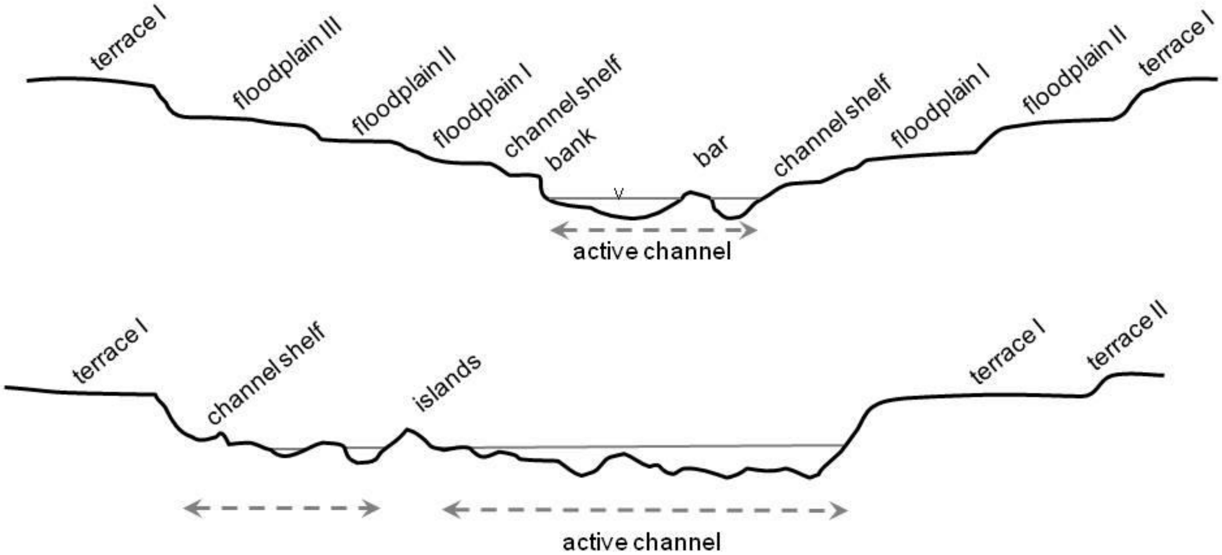


Figure 6. Idealized channel cross-sections showing active channel, islands and bars, channel shelf, floodplains, terraces and transitions. Meandering or straight stream in top frame; braided stream in lower frame. Islands are in channel features that are vegetated; bars are non-vegetated to partially vegetated and part of the active channel. Active channel in the lower frame –a braided channel– is the sum of the three active channels.

*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 with a rod and level or total station 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 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. Between surveyed vegetation points (or quadrats), distance along the tape and elevation are recorded at every major break in topography (following guidelines in Harrelson et al. 1994). Record the start and stop distance of each of the classified fluvial features. Along each transect, position of active channel boundaries, lowest extent of perennial vegetation on islands, and water's edge is be surveyed. If the stream channel orientation varies more than 10 degrees from the valley transect orientation, the active channel should be surveyed perpendicular to the channel orientation, crossing the valley transects at the stream centerline.

*Reach Longitudinal Profile*

Longitudinal profiles of the bed and water surface of the entire reach is surveyed along the channel centerline (refer to Harrelson et al. 1994). Points along the thalweg, i.e., 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. Longitudinal profile may be plotted in the field to assure that the reach is uniform (no major breaks in slope along the reach).

In cases where surveying cross sections is impractical or impossible, at a minimum active channel width is recorded through the reach. Some streams may present difficulties in taking many of the measurements outlined above (e.g., beaver ponding, multiple channels, natural lakes). Suggestions for such cases are given in Appendix 5.



**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. Additional information on analysis may be found in Mueller-Dombois and Ellenberg (2002) and Elzinga et al. (2001).

Having taken the core set of measurements outlined above, many quantitative summary attributes of the site can be made, including: species composition, richness and biodiversity of the site, percent non-native species, proportions of various plant functional groups, frequency/abundance of individual species, total basal area of woody species, density and size-class structure of trees by species, vertical structure of vegetation, habitat heterogeneity, channel form, width to depth ratio of channel, channel gradient, and many others. These measures can be used to track changes in the important site attributes through time, to compare a particular site to another, or reaches along a segment may be used to make inference to a stream segment for comparison with another or tracking larger-scale changes through time. Sites may also be rated and compared using a composite Riparian Structural and Compositional Complexity (RSCC) score presented in Chapter 6 of the Riparian Technical Guide. This score uses the quantitative information from the core protocol to provide a rating of site conditions to compare reaches along like valley types together.

In addition to the data provided by the core protocol, the basic framework may be augmented when specific objectives for a study have been identified. The table in Appendix 6 provides some examples of attributes that should be added to the core protocol for changes to riparian areas that might 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 water 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 can be assessed using the hydrological alteration add-ons to the core protocol. Adding the *physical alteration* metrics to the core protocol may be 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 may be quantified using the physical alteration add-ons to the core protocol. Finally, questions regarding livestock and wildlife grazing and/or browsing, forestry practices in riparian areas, mowing or hay cutting, agriculture, wildfire or any other activities that physically remove vegetation biomass can be addressed through the *vegetation removal* add-ons to the core protocol. Regardless of the objectives for using the riparian protocol, it is recommended that the core attributes (Appendix 6) be measured and tailored to study or project objectives.

## Literature Cited


Auble, G.T., J.M. Friedman, M.L. Scott. 1994. Relating riparian vegetation to present and future streamflows. Ecological Applications 4:544-554.

Auble, G.T., M.L. Scott , J.M. Friedman. 2005. Use of individualistic streamflow-vegetation relations along the Fremont River, Utah, USA to assess impacts of flow alteration on wetland and riparian areas. Wetlands 25:143-154.

Bisson, P.A., J.M. Buffington, D.R. Montgomery. 2006. Valley segments, stream reaches, and channel units *in* Hauer, F.R. and G.A. Lamberti, *Methods in Stream Ecology*, Academic Press, New York.

Burton, T.A., E.R. Cowley, and S.J. Smith. 2007. *Monitoring Stream Channels and Riparian Vegetation- Multiple Indicators.* USDI Bureau of Land Management, Idaho Technical Bulletin 2001-01, Boise, ID.

Carlson E A 2009 Fluvial Riparian Classification for National Forests in the Western United States. In Graduate Degree Program in Ecology. p. 212. Colorado State University, Fort Collins, Colorado.

Coles-Ritchie, M. 2002. Effectiveness monitoring for streams and riparian areas within the Upper Columbia River Basin *in* Kershner, J.L., M. Coles-Ritchie, E. Cowley, R.C. Henderson, K. Kratz, C. Quimbly, D.M. Turner, L.C. Ulmer, and M.R. Vinson. *A Plan to Monitor the Aquatic and Riparian Resources in the Area of PACFISH/INFISH and the Biological Opinions for Bull Trout, Salmon and Steelhead.* USDA Forest Service Internal Report.

Cooper, D.C., D.M. Merritt, D.C. Andersen, and R.A. Chimner. 1999. Factors controlling the establishment of Fremont cottonwood seedlings on the upper Green River, U.S.A. Regulated Rivers: Research and Management 15:419-440.

Cronk, J. and M. Fennessy. 2001. *Wetland Plants: Biology and Ecology.* Lewis Publishers, New York, New York.

Dethier, M. N., E.S. Graham, S. Cohen, L.M. Tear. 1993. Visual versus random-point percent cover estimations: "objective" is not always better. Marine Ecology Progress Series 96:93-100.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 2001. *Measuring and Monitoring Plant Populations.* Bureau of Land Management Technical Reference 1730-1, Denver, CO.

Floyd, D. A. and J. E. Anderson. 1987. A comparison of three methods for estimating plant cover. Journal of Ecology 75: 221-228.

Frissell, C.A., W.J. Liss, C.E. Warren, and M.D. Hurley. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. Environmental Management 10:199-214.

Harrelson, C.C., C.L. Rawlins, and J.P. Potyondy. 1994. *Stream Channel Reference Sites: an Illustrated Guide to Field Technique*. USDA Forest Service General Technical Report RM-245. Available at: http://www.stream.fs.fed.us/ publications/documentsStream.html

Heady, H. F., R.P Gibbens, and R.W. Powell. 1959. A comparison of the charting, line intercept, and line point methods of sampling shrub types of vegetation. Journal of Range Management 12: 180-188.

James-Pirri, M., C.T. Roman, and J.F. Heltshe. 2007. Power analysis to determine sample size for monitoring vegetation change in salt marsh habitats. Wetland Ecology and Management 15:335-345.

Larcher, W. 2003. *Physiological Plant Ecology: Ecophysiology and Stress Physiology of Functional Groups*. Springer-Verlag, Berlin, 4th edition.

Legendre, P. and L. Legendre. 1998. *Numerical Ecology*. Elsevier Science, Amsterdam.

Leopold, L.B. and T. Maddock. 1953 The hydraulic geometry of stream channels and some physiographic implications. U.S. Geological Survey Professional Paper 252, Washington, D.C.

Lisle, T.E. 1986. Stabilization of a gravel channel by large streamside obstructions and bedrock bends, Jacoby Creek, northwestern California. Geological Society of America Bulletin 97:999-1011.

Mitchell, K. 2007. Quantitative analysis by the point-centered quarter method. Department of Mathematics and Computer Science, Hobart and William Smith Colleges, Geneva, NY. Available at: http://faculty.wwu.edu/wallin/envr442/pdf_files/PCQM.pdf

Montgomery, D.R. and J.M. Buffington. 1997. Channel-reach morphology in mountain drainage basins. Geological Society of America Bulletin 109:596-611.

Mueller-Dombois, D. and H. Ellenberg. 2002. *Aims and Methods of Vegetation Ecology*. The Blackburn Press, New Jersey.

Peck, D.V., J.M. Lazorchak, and D.J. Klemm (editors). Unpublished 2003 draft. *Environmental Monitoring and Assessment Program -Surface Waters: Western Pilot Study Field Operations Manual for Wadeable Streams.* EPA/XXX/X-XX/XXXX. U.S. Environmental Protection Agency, Washington, D.C.

Platts, W.S., C. Armour, G.D. Booth, M. Bryant, J.L Bufford and others. 1987. *Methods for Evaluating Riparian Habitats with Applications to Management*. USDA Forest Service General Technical Report INT-221, Ogden, UT.

Poole, G.C., C.A. Frissell, and S.C. Ralph. 1997. In-stream habitat unit classification: inadequacies for monitoring and some consequences for management. Journal of the American Water Resources Association 33:879-896.

Prichard, D. et al. 1993. Riparian Area Management: Process for Assessing Proper Functioning Condition. Technical Reference 1737–9, Bureau of Land Management, U.S. Department of the Interior, Denver, Colorado.

Rains, M.C., J.E. Mount, E.W. Larsen. 2004. Simulated changes in shallow groundwater and vegetation distributions under different reservoir operations scenarios. Ecological Applications, 14:192-207.

Ries III, K.G., P.A. Steeves, J.D. Coles, A.H. Rea, and D.W. Stewart. *StreamStats: A U.S. Geological Survey Web Application for Stream Information, U.S.* Department of the Interior, U.S. Geological Survey, http://water.usgs.gov/osw/ streamstats/. Page Contact Information: GS-W_Streamstats@usgs.gov

Scott, M.L., P.B. Shafroth, and G.T. Auble. 1999. Response of riparian cottonwoods to alluvial water table declines. Environmental Management 23:347-358.

Scott, M.L. and E.W. Reynolds. 2007. *Field-based Evaluations of Sampling Techniques to Support Long-term Monitoring of Riparian Ecosystems along Wadeable Streams on the Colorado Plateau*. U.S. Geological Survey Open File Report 2007-1266.

Sigafoos, R.S. 1964. Botanical evidence of floods and floodplain deposition. U.S. Geological Survey Professional Paper 485-A.

Stromberg, J.C., S.J. Lite, T.J. Rychener, L.R. Levick, M.D. Dixon and J.M. Watts. 2006. Status of the riparian ecosystem in the upper San Pedro River, Arizona: application of an assessment model. Environmental Monitoring and Assessment 115:145-173.

Tyree, M.T., K.J. Kolb, S.J. Rood, S. Patino. 1994. Vulnerability to drought induced cavitation of riparian cottonwoods in Alberta: A possible factor in the decline of the ecosystem? Tree Physiology 14:455-466.

Winward, A.H. 2000. *Monitoring the Vegetation Resources in Riparian Areas*. USDA Forest Service, Rocky Mountain Research Station Technical Report RMRS-GTR-47, Ogden, UT.

## Appendix 1. Field sampling at a glance.

*Vegetation Sampling*

| **Task 1: Measure Presence of Woody and Herbaceous Vegetation** | | |
|---|---|---|
| Step | Description | Reference |
| 1 | Starting from a random point on 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. The first species viewed or "hit" with the laser is recorded. Move this layer of vegetation out of the way and continuing recording "hits" until ground cover or the limit of upper canopy is reached. | pgs. 13-15 |
| 2 | If data on the vertical structure are required, record the height of the vegetation as one of the following categories: Low Vegetation (<1m), Mid-story Vegetation (1-5m), Canopy (>5m). Note that the presence of a species is recorded only once per height class. | pg. 16 |
| 3 | Ground cover is recorded only once, occurring after the last vegetation "hit" in the down direction is recorded. Groundcover categories are: :<br>**Physical** / **Organic**<br>Bare soil (soil particles <2 mm) / Basal Vegetation<br>Gravel (2 – 64 mm) / Bryophyte<br>Cobble (65 – 256 mm) / Wood<br>Boulder (> 256 mm) / Litter: leaf, needle litter, and other dead plant material or animal droppings<br>Bedrock<br>Water | pgs. 16-17 |
| **Task 2: Measure Tree Stem Density, Basal Area and Condition** | | |
| 1 | Belt transects oriented parallel to point intercept transects are established along each transect. | pg. 17 |
| 2 | Measure the diameter of each tree species falling within the belt transects 1.37 m above the ground. For individuals less than 25 cm tall, measure basal diameter. | pg. 17 |
| 3 | Asses canopy condition of identified trees using the following categories:<br>**Canopy Condition** / **Criteria**<br>Critically stressed / Major leaf death and or branch die back (>50% of canopy volume affected)<br>Significantly stressed / Prominent leaf death and/or branch die back (20-50% of canopy volume affected)<br>Stressed / Minimal leaf death and or branch die back (<20% of canopy volume affected)<br>Normal / Little or no sign of leaf water stress/no water stress related leaf death<br>Vigorous / No sign of leaf water stress/very healthy looking canopy | pgs. 17-18, Table 3 |
| 4 | Assess potential canopy for all tree species. This is estimated as a visual determination of the percentage of live canopy relative to crown volume. | pg. 18-20, Figure 4 |
| **Task 3: Plant Specimen Collection** | | |
| 1 | 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. | pg. 20 |

*Channel Measurements*

| **Task 1: Geomorphic Classification of Fluvial Surfaces** | | |
|---|---|---|
| Step | Description | Reference |

| | | |
|---|---|---|
| 1 | Walk transects from end to end to determine obvious breaks in geomorphic surfaces. | pg. 20 |
| 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. 20-22, Table 5 and Figure 5 |
| **Task 2: 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. 22 |
| **Task 3: 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. 23 |
| 2 | Record start and stop distance of each of the classified fluvial features. | pg. 23 |
| 3 | Along each transect, survey the position of active channel boundaries, lowest extent of perennial vegetation on islands, and water's edge. | pg. 23 |
| **Task 4: 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. 23 |
| 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. 23 |
| 3 | Plot longitudinal profile in the field to assure that the reach is uniform (no major breaks in slope along the reach). | pg. 23 |

**Appendix 2. Gear list for line point intercept method.**

Essential

- Protocol (this document)
- Forms (copies from Appendix 7)
- 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)
    - 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)
- Laser rangefinder or sonic distance meter
- GPS unit
- Camera (spare memory and batteries)
    - Photo scale
    - Board or card for identifying photo location
- Notebook (waterproof)
- Topographic map of site
- Aerial photograph of site
- Calculator

## Appendix 3. Random numbers for 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 | 10 | 1 | 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 |
| 4 | 8 | 5 | 5 | 8 | 9 | 1 | 10 | 4 | 6 | 3 | 7 | 8 | 3 | 5 | 4 | 2 | 5 |

**Appendix 4. 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 (Figure A4-1). In a similar way, the mean or variance of a variable of interest could be plotted as a function of number of points (Figure A4-1). The number of transects may also vary depending on the variables of interest, the objectives of the monitoring, and time and resources available.

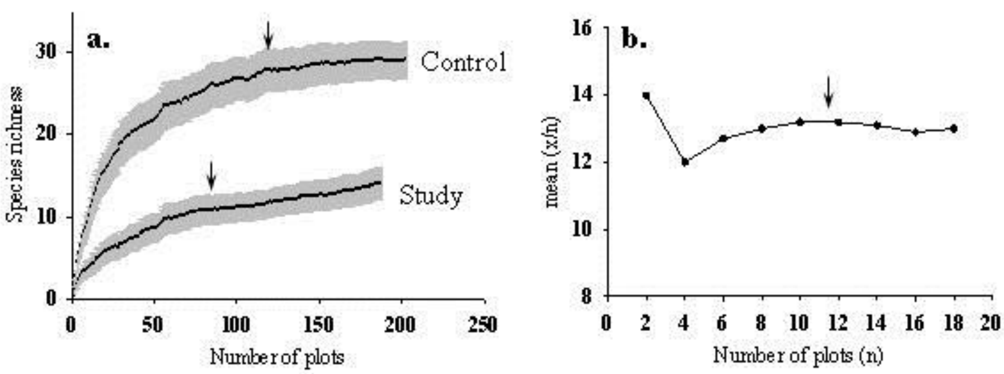


Figure A4-1. Examples of methods for determining adequate numbers of points (or plots) to establish at sites based upon different measurement objectives: a) species accumulation curves with arrows indicating asymptote and adequate number of samples to estimate species richness along a control and study reach; b) plot of running mean of a variable of interest (x) indicating that 8-10 plots are adequate (redrawn from Mueller-Dombois and Ellenberg 2002).

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).

**Appendix 5. Special cases**

Some riparian areas are not conducive to the site layout described above. 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, etc.) 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% 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% 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. If it is not feasible to sample the entire valley bottom, use a set transect length (refer to Table 1).

**Springs -** For springs use the GDE protocol, which includes sampling of the spring and 20 m of the spring creek. The spring creek beyond 20m of the spring could be sufficiently sampled with the core riparian protocol ( i.e., 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 and the water table, 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 6. Objective-based add-ons to the core riparian protocol. Additional monitoring attributes and their relationship to key monitoring questions or study objectives.**

| 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 7. Vegetation data field forms.**

Riparian Core Protocol Data Form: Line Point Intercept

Page__of__

| | | | |
|---|---|---|---|
| Study | | Bearing | Date |
| Reach | | Examiner | |

| Transect | Distance from left pin (m) | Species Height <1.5 m | Ground cover[1] | Species Height 1.5 to 5 m | Species Height > 5 m | Fluvial setting[2] |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

[1]Cover classes: Si – bare silt or clay, Sa – bare sand, G – gravel, P – pebble, C – cobble, BL – boulder, BR – bedrock, W – water, BV – basal vegetation, BY – bryophyte, W – wood, L – litter. [2]Fluvial setting : CH – channel, B – bank, FP1 – floodplain 1, FP2 – floodplain 2, T1 – terrace 1, I – island, BC – back channel, Tr – transition, etc. (record actual distance of breaks).

Riparian Core Protocol Data Form: Trees

Page__of__

| | | | |
|---|---|---|---|
| Study | | Bearing | Date |
| Reach | | Examiner | |

| Transect | Distance interval from left pin (m) | Species | Tree diameter (cm) | Condition class[1] |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

[1]Canopy classes: C – critically stressed (>50% of canopy affected), SS – significantly stressed (21-50%), S – stressed (11-20%), N – normal (5-10%), V – vigorous (<5% of canopy affected).