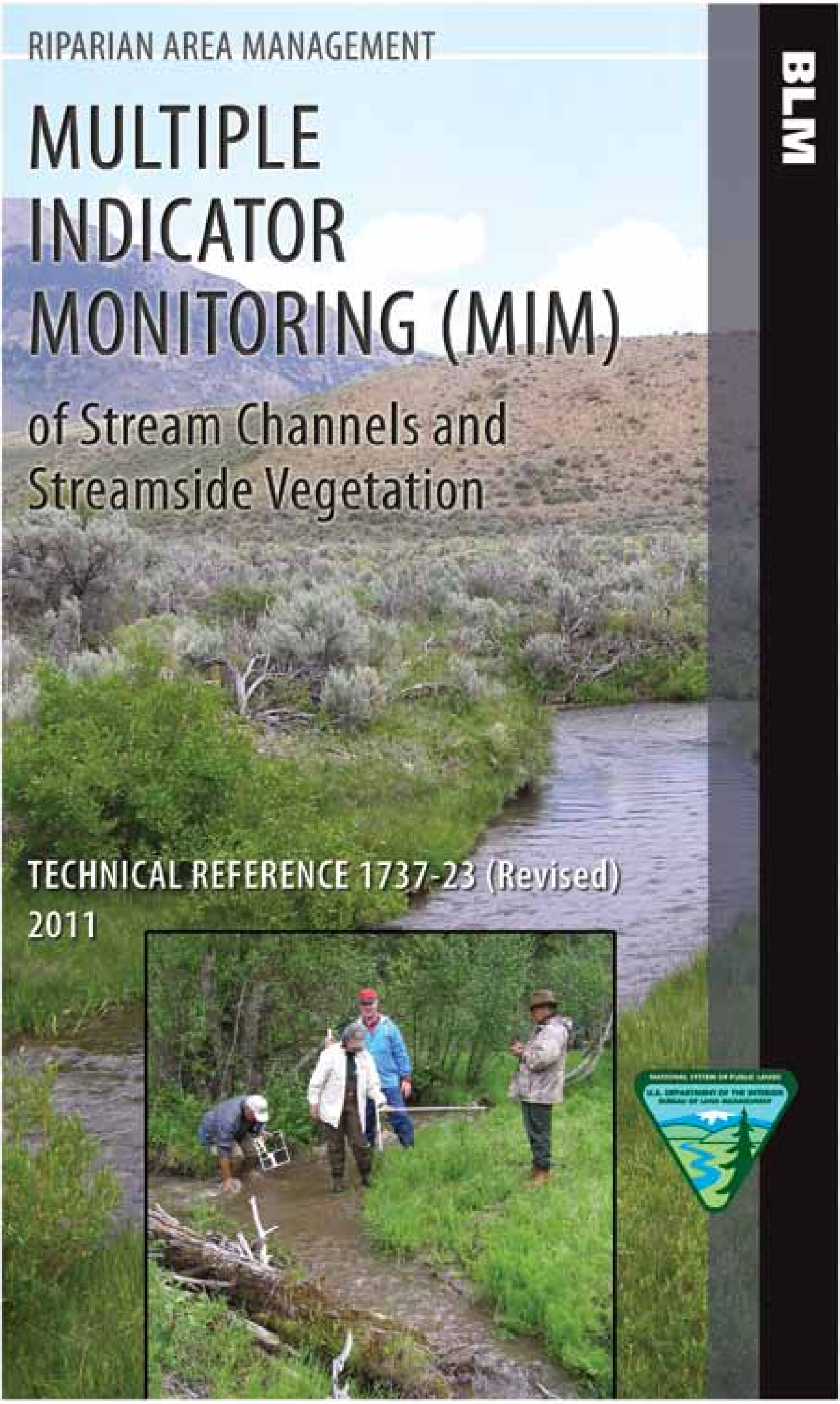

RIPARIAN AREA MANAGEMENT

MULTIPLE INDICATOR MONITORING (MIM)

of Stream Channels and Streamside Vegetation

TECHNICAL REFERENCE 1737-23 (Revised)
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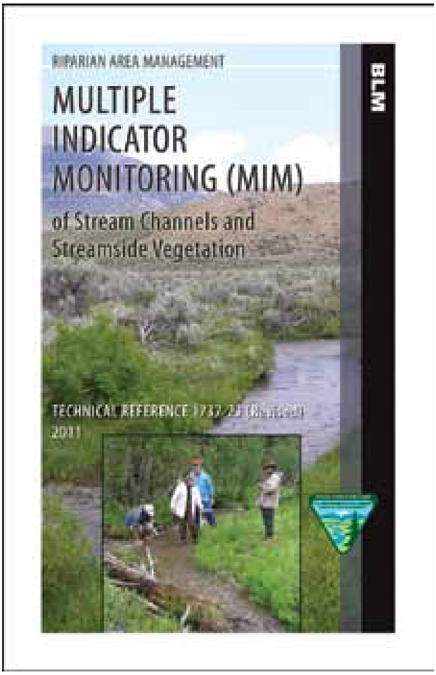

Multiple Indicator Monitoring (MIM) of Stream Channels and Streamside Vegetation

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PREFACE

Interest in riparian area management has increased tremendously over the past 25 years. This interest has created a growing need to effectively monitor the attributes and processes that occur in these valuable systems. Monitoring the most sensitive attributes is critical to understanding how management influences streams and riparian areas. Monitoring within stream channels and at their margins is particularly useful to the management of stream-dependent resources, including water quality and quantity, aquatic biota, and near-stream terrestrial biota (Winward 2000).

Due to the widespread use of stubble height for monitoring and managing riparian areas by the Federal land management agencies, in 2003, the U.S. Department of the Interior (USDI) Bureau of Land Management and U.S. Department of Agriculture (USDA) Forest Service commissioned the University of Idaho to evaluate how the agencies were applying stubble height. As a result, the university established a study team consisting of researchers, university professors, livestock producers, and agency technical specialists. Based on their findings, the team recommended that monitoring not be limited to just short-term, livestock grazing use indicators, but that it also focus on indicators of long-term resource conditions to determine if objectives are being met. In addition, the team recommended that data from multiple indicators (short- and long-term) needed to be statistically reliable to provide a sound basis for management decisions (University of Idaho Stubble Height Review Team 2004).

The multiple indicator monitoring (MIM) protocol was developed in response to the team's recommendations. It is based on the following objectives: 1) address multiple short- and long-term indicators, 2) measure the most important indicators relevant to detecting change, 3) use existing procedures to the extent possible, 4) improve efficiency through the use of electronic data collection, 5) yield statistically acceptable results within realistic time constraints, and 6) provide useful data to inform management decisions.

The development of the MIM protocol is intended to foster increased and focused efforts to collect fundamental and much needed riparian monitoring data. Developing, testing, and peer review of this protocol have resulted in additions, deletions, and refinements to the procedures described in Burton et al. (2008) and previous versions, and revisions have been made to improve applicability, statistical reliability, and efficiency.

ACKNOWLEDGMENTS

The "multiple indicator monitoring" concept was originally the vision of members of the Interagency Stubble Height Review Team composed of:

Dr. Larry Bryant, Rangeland Ecologist, USDA Forest Service

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Ron Wiley, Team Leader, National Riparian Service Team (Retired), USDI Bureau of Land Management

The development of this protocol would not have been possible without the review and comments made by a distinguished panel of experts, including:

Dr. John Van Sickle, Environmental Statistician, Western Ecology Division, U.S. Environmental Protection Agency

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There were many anonymous contributors as well.

We acknowledge the many comments and suggestions received during the past 6 years of testing from numerous individuals at training sessions held throughout the West. This input shaped the protocol and enforced its underlying philosophy of efficiency, effectiveness, and applicability to land management.

We also respectfully acknowledge the invaluable pioneering riparian work of Dr. Alma Winward, Ecologist (Retired), USDA Forest Service.

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I. INTRODUCTION

Multiple Indicator Monitoring (MIM) of Stream Channels and Streamside Vegetation was developed to provide information necessary for managers, landowners, and others to adaptively manage riparian resources. Through 6 years of testing, continuous improvements have been made to this protocol to minimize subjectivity while maintaining a reasonable level of precision and accuracy. The MIM protocol is designed to be objective, efficient, and effective for monitoring streambanks, stream channels, and streamside riparian vegetation. Indicators and procedures in this protocol were selected and developed primarily to monitor impacts of livestock and other large herbivores on wadable streams (usually less than 10 m wide). The MIM protocol integrates annual grazing use and long-term trend indicators allowing for evaluation of livestock grazing management. Because the MIM protocol includes procedures for documenting stream condition and trend, users will also find that the long-term indicators described in this protocol are useful for monitoring changes that occur on the streambank and in the channel as a result of management activities other than grazing. The MIM protocol was developed and tested on relatively low-gradient (less than 4 percent), perennial snowmelt-dominated and spring-fed streams in the Western United States and is most applicable to those systems. Streamside riparian and wetland vegetation is a critical component within those systems for stabilizing physical stream processes and functions that influence streambank stability and channel geometry.

Previous monitoring approaches have been relatively inefficient partly because they addressed only one or two indicators at a time. Greenline vegetation would be gathered using the Winward method, for example, and then in separate sampling, stubble height would be obtained using the methods in USDI, BLM (1996b). Sometimes data were acquired using different stream reaches at varying times of the year, making it difficult to develop relationships between grazing influences and the observed stream conditions. The MIM protocol combines observations of up to 10 indicators along the same stream reach into one protocol, using mostly simple adaptations of existing procedures. Travel to field sites represents a considerable time commitment, so the collection of more than one indicator at one location with one protocol likely saves time and is more efficient.

Elzinga et al. (1998) defined monitoring as "the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective." In contrast, inventory is "the systematic acquisition and analysis of information needed to stratify, describe, characterize, or quantify resources for land-use planning and management of the public lands" (USDI, BLM 1996a). Information derived from inventory, such as characterization and stratification, is an important part of establishing a monitoring program. Because the location of monitoring sites is a critical component of obtaining useful monitoring data, the MIM protocol addresses stratifying riparian vegetation complexes and stream segments and locating designated monitoring areas (DMAs). The DMA is the location on the stream where all monitoring procedures described in this protocol occur.

This protocol includes procedures for monitoring 10 indicators. Three indicators provide data from which short-term livestock (or other herbivore) use information can be derived:

1. Stubble height (adapted from USDI, BLM 1996b) and Challis Resource Area (1999)
2. Streambank alteration (Cowley 2004)
3. Woody species use (adapted from USDI, BLM 1996b)

Short-term indicators provide information necessary to help determine whether the current season's livestock grazing is meeting grazing use criteria. They can be used as early warning indicators that current grazing impacts may prevent the achievement of management objectives and can also be used to help explain changes in riparian vegetation and channel conditions over time.

Seven indicators provide data from which long-term resource condition information can be derived:

1. Greenline composition (adapted from Winward 2000 and USDI, BLM 1996a)
2. Woody species height class (Kershner et al. 2004)
3. Streambank stability and cover (adapted from Kershner et al. 2004)
4. Woody species age class (adapted from Winward 2000)
5. Greenline-to-greenline width (Burton et al. 2008)
6. Substrate (Bunte and Abt 2001)
7. Residual pool depth and pool frequency (Lisle 1987)

Long-term indicators provide data to assess the current condition and trend of streambanks, channels, and streamside vegetation. They help determine if local livestock grazing management strategies and other land management actions are making progress toward achieving the long-term goals and objectives for streamside riparian vegetation and aquatic resources.

In addition to providing procedures for monitoring the 10 indicators described above, the MIM protocol suggests establishing permanent photo points. Photo points provide visual records of long-term streambank and riparian vegetation condition and trend.

To facilitate data recording and analysis, two Microsoft Excel applications were developed as part of the MIM protocol. The Data Entry Module is for entering data into handheld computers using Windows Mobile in the field. These devices save about 1 hour per DMA compared with recording on paper. However, the data may be recorded on the MIM Field Data Sheet (see appendix B) if a handheld computer is not available.

The Data Analysis Module provides calculations of various metrics (see chapter V) and permits analysis of the data. These metrics are used as indicators of streamside vegetation use and vegetation and stream channel conditions. The Data Analysis Module requires a computer with full versions of Windows and Excel. The Data Analysis Module provides a format to export the summary data to a local MIM database, which is a Microsoft Access database used to store metric summary data for future reference, evaluate conditions and trends through time, and develop reports. This database is designed for individual units and does not represent a national agencywide database. A national geodatabase will be developed by the BLM to accommodate MIM data. Data analysis within the MIM protocol addresses precision, the ability to detect change, and minimizing observer variability and subjectivity through an emphasis on strict compliance with rule sets and required training. Interpretation and evaluation are also discussed relative to assessing trends and providing useful information to support adaptive management.

This document is organized according to the order in which this protocol is conducted: 1) select the designated monitoring area; 2) locate the greenline; 3) measure indicators using systematic procedures and metrics; 4) use the Data Entry and Data Analysis Modules and the MIM database; and 5) analyze, interpret, and evaluate monitoring data.

II. SELECT THE DESIGNATED MONITORING AREA (DMA)

A. Determine Monitoring Objectives

Monitoring objectives should be determined quantitatively for each DMA. These objectives often drive the kind of DMA selected for monitoring (representative, critical, or reference DMA as described later in this chapter). Broad-scale objectives developed in land use plans should be carefully evaluated to ensure the riparian complex associated with the DMA has the potential to meet them. If a reference in the same riparian complex is available, objectives may be quantified by measuring the indicators within the reference DMA. When the potential of the riparian complex is not known, interim objectives may be developed and refined as more data become available.

B. Stratify the Stream Reach

The stratification process divides stream reaches into segments with similar vegetation and physical characteristics, thereby increasing efficiency by focusing on important parts of the stream. Streams are first stratified according to riparian complexes and land uses. Riparian complexes are defined by overall geomorphology, substrate characteristics, stream gradient, and vegetation patterns along the stream. They develop and function in response to the interacting features of valley bottom gradient, geology and soil characteristics, valley bottom width, elevation, and climate (Winward 2000).

Streams are usually stratified by using the following: valley bottom type (Rosgen 1996), dominant soil family (USDA, Forest Service 1992), stream profile or gradient, vegetation patterns along the stream (as viewed from aerial or satellite photography), stream channel type (Rosgen 1996), and land uses, including pastures within an allotment. An example is shown in figure 1. Within the grazed unit, there are two complexes or strata. Complex B is wider and dominated by shrubs. Complex C is narrower and dominated by herbaceous vegetation types adjacent to the stream. Note that the B and C complexes form repeating patterns in the upstream direction. The repeating sequences of the B and C complexes reflect the influence of side valley fans that locally affect stream gradient, soil type, and, therefore, valley width and dominant streamside vegetation types.

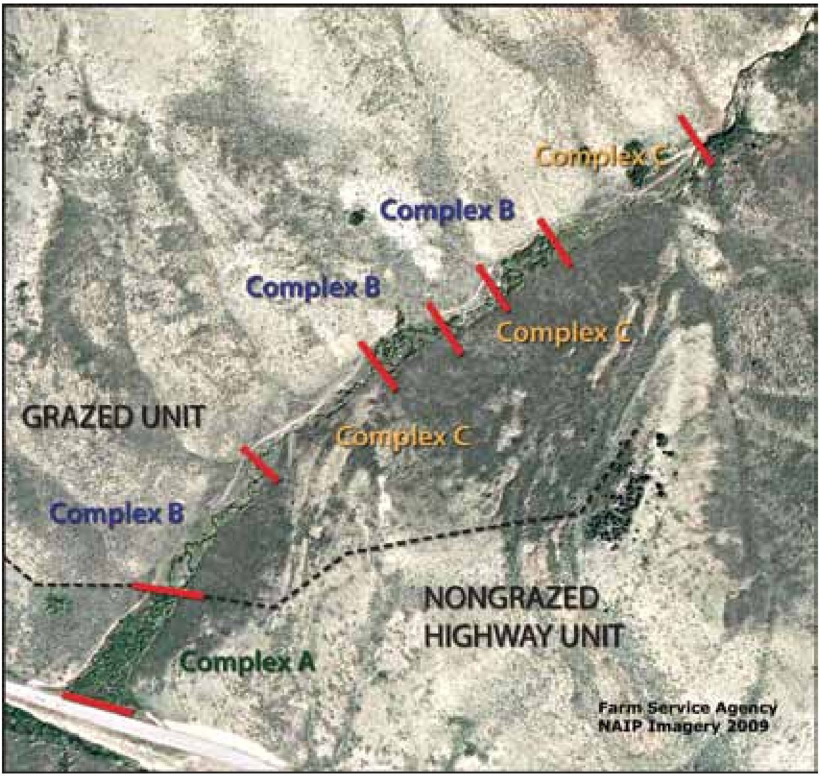


Figure 1. Reach stratification on Telephone Draw near Montpelier, Idaho. Note repeating complexes within the grazed unit (pasture). Complex "A" is likely the same riparian/stream type as "B" but because it is located outside of the grazed unit, it is a different land use and is thus given a different name or identifier.

The stratification of the stream should be conducted by an experienced interdisciplinary team and documented thoroughly. The interdisciplinary team must provide clear and comprehensive rationale for the stream stratification and identification and the selection and delineation of the complexes. This rationale should include a short discussion of the DMA selection process and the intent of collecting data at that site.

Once the stream has been stratified within the grazed unit, one or more complexes are selected for monitoring. The complex selected depends upon the monitoring objectives. Generally, the complexes that are the most sensitive to management influences should be used for monitoring. Once the most sensitive complexes are located, the location of the DMA is randomly selected as described in this chapter, which results in a stratified random sampling design.

C. Establish the DMA

A DMA is a permanently marked segment of a stream at least 110 m long that has been selected for monitoring. Longer segments may be needed for monitoring larger streams (having a greenline-to-greenline width or GGW of more than 5.5 m). For such streams, the DMA should be at least two meander lengths or approximately 20 times the GGW. For example, a DMA on a stream segment with an average GGW of 8.3 m would be 8.3 m x 20, or 166 m in length.

The DMA concept was initially established for grazing management applications, but DMAs may also be used to monitor recreation impacts, the effects of roads, and other activities. **It is important that DMAs are established by an interdisciplinary team of highly experienced personnel with knowledge of the management area.**

There are three types of DMAs:

- **Representative DMA:** A representative DMA is a monitoring site in a riparian complex that is representative of a larger area. This is the most common type of DMA used by land managers. Representative DMAs should be located within a single riparian complex.

  When more than one riparian complex occurs in a management unit, the DMA should be placed in the riparian complex that is the most sensitive to management influences. The premise is that if the DMA is placed in the most sensitive complex and that complex is being monitored and managed to achieve desired conditions, then the other less sensitive complexes will also be managed appropriately.

  The criteria for selecting representative DMAs are that:

  - The riparian complex for the DMA is selected by an experienced interdisciplinary team.

  - The DMA is located in a complex that represents and is accessible to the management activities of interest.

  - The DMA is randomly located in the riparian complex that is the most sensitive to the management activities of interest. When the most sensitive riparian complex is spatially discontinuous within a management unit (i.e., multiple subsections or reaches of the same complex are interrupted by other complexes), the subreach selected for the DMA location is randomly chosen.

  - Within the most sensitive complex, the DMA is located on a site that is sensitive to disturbance and is not located on reaches impervious to disturbance (for monitoring streambank stability and streambank alteration). Such reaches may be appropriate for monitoring woody species age class and woody species use.

  - The DMA will respond to the management influence of interest and resource objectives can be achieved at the DMA; i.e., the site has the potential to respond to and demonstrate measureable trends in condition resulting from changes in grazing management or other management activities influencing stream channels and riparian vegetation (also applicable to a reference DMA).

  - The gradient of the stream reach at the DMA is generally less than 4 percent. The gradient may exceed 4 percent if the reach has a distinctly developed floodplain and the riparian vegetation heavily influences channel stability (also applicable to a reference DMA).

  - The DMA is located outside of a livestock concentration area. DMAs should not be located at water gaps or locations intended for livestock concentration or in areas where riparian vegetation and streambank impacts are the result of site-specific conditions (such as along fences where livestock grazing use is not representative of the riparian area). These local areas of concentration may be monitored to address highly localized issues if necessary (in which case, they would be described as critical DMAs as defined in the next section).

  - The DMA is free from the influence of compounding activities. DMAs should not be located in areas compounded by activities that make it difficult to establish cause-and-effect relationships. For example, an area used heavily by both recreationists and livestock would not make a good DMA to determine the effects of livestock grazing on stream conditions.

- **Critical DMA:** A reach that is ***not*** representative of a larger area but is important enough that specific information is needed at that particular site is a critical DMA. Critical DMAs are monitored for highly localized purposes and to address site-specific questions. For example, small critical spawning reaches may be monitored when there is concentrated livestock use. Extrapolating data from a critical DMA to a larger area may not be appropriate within the complex containing the critical area. A critical DMA does not have to meet the criteria for a representative DMA.

- **Reference DMA:** A reach chosen to obtain reference data useful for identifying potential condition and for establishing initial desired condition objectives for a similar riparian complex is a reference DMA. A common example is a grazing exclosure where livestock access to the stream is restricted. Ungrazed references used for reference DMAs need to be carefully analyzed to ensure their usefulness as a comparison. Reference DMAs meet many of the same criteria as representative DMAs.

When the monitoring objective is to assess management effects over time, both a representative DMA and reference DMA might be used. For example, referring back to figure 1, complex A could be chosen as the reference DMA since it is outside of the grazed unit and complex B as the representative DMA since it is common within the pasture and comparable in channel and vegetation characteristics to the reference complex. If the monitoring objective is to assess management effects on cutthroat trout habitat, a critical DMA might be established in complex C where spawning or some other critical life history requirement is concentrated.

The number of DMAs per grazing unit depends on the resource values in the area. Usually, one measured DMA per pasture is adequate. Supplemental DMAs, with photographs only, may be included in addition to the measured DMA to validate that the representative DMA actually is characteristic of the conditions throughout the complex.

D. Set Up the DMA

1. ***Select a Random Starting Point:*** Randomly locate the starting point (lower end) of the DMA within the selected complex. A good way to randomly select the starting point is to measure the total length of the stream in the selected complex, subtract 110 m from the total length of the stream, then select a random number between 1 and the difference. For example, if the stream within the complex is 465 m, a random number between 1 m and 355 m (465 m – 110 m = 355 m) would result in a random starting point. When the location has been determined, check the site against the DMA criteria. If the DMA does not meet the criteria, another random point is selected and the process is repeated.

2. ***Mark the DMA:*** Once the DMA is selected, a permanently marked DMA sample reach is established. The following procedure should be followed when establishing the reach:

   a. **Permanently Mark the Lower and Upper Ends of the Sample Reach with Markers:** Place the lower marker (starting point) on the left-hand side (looking upstream) and the upper marker 110 m upstream (farther if a longer reach is used) on the right-hand side. The marker should be located at least 2 m away from the top of the bank to reduce the risk of losing the marker. Reach markers should be made of securely capped or bent-over rebar or similar material. Straight, jagged, rebar stakes present a serious hazard to animals.

b. Place a Permanent Marker as a Reference Point to Help Relocate the DMA: Reference markers are needed as a way to relocate the DMA since rebar is often difficult to find. Reference markers should be located well away (at least 33 m) from the DMA sample reach. Reference markers can be steel posts, a marked post in a fence line, a marked tree or unique rock, or other natural feature. Be aware that single steel posts tend to attract livestock and can create concentrated impacts where they are placed.

c. Document the Location of the Markers: Provide a global positioning system (GPS) location in **degree decimal latitude and longitude** for both the reach markers and the reference marker. Universal Transverse Mercator (UTM) coordinates are optional. Also record the datum and the zone. Sketch the monitoring setup to ensure the same starting point on the stream is used during future visits. Use the Header spreadsheet in Data Analysis Module (as discussed in chapter V) to document the location from a sketch and/or satellite photograph.

d. Take Photographs: After the DMA markers are placed, photographs should be taken before data are collected because the monitoring process may result in some visible disturbance to the site. At a minimum, take photographs (showing the marker) at the following locations:

- From the lower marker looking upstream
- Across the stream from the lower marker
- Downstream from the upstream marker
- Across the stream from the upstream marker

Take additional photographs as needed and describe the location of each photo in relation to the downstream marker.

E. Follow Monitoring Guidelines and General Procedures

1. Determine Which Indicators to Monitor: Use only the indicators and corresponding procedures appropriate for the site that will help answer monitoring questions. For example, if there are no monitoring questions related to the condition of the streambed, do not collect substrate data. If the site does not have the potential for woody species with appropriate management, do not include the woody species age class and woody species use data as part of the monitoring for the site. However, if the site objectives include woody species, but no woody species are present, woody species should be included to document their establishment as the site recovers.

2. Determine When to Monitor: The procedures in the MIM protocol are designed to be completed at low waterflows. High waterflows obscure greenlines and streambanks. Attempts to collect data during these periods will greatly limit the usefulness of the data. These monitoring procedures should not be used immediately following a flood or high-flow event resulting in sediment deposition and scour. Sediment deposition and scour make it difficult, if not impossible, to determine the effects of current season livestock use, and some vegetation may be temporarily buried. Because estimates of trend are made at each individual DMA, the source of variability associated with temporal variation may be introduced if resampling is not done at the same time of year. The best time to sample vegetation is when the plants are flowering. However, this occurs at different times during the growing season. To accurately evaluate trend on greenlines, it is important to obtain repeat samples during the same stage of seasonal progression or the same time period that baseline data was collected. For example, if seasonal runoff occurred early during the year that baseline data was gathered, and sampling was done about a month after the high flows, every effort should be made to collect repeat data under the same conditions that were present when baseline data was collected, even if it occurs later or earlier in the season. Thus, if monitoring was previously conducted prior to or well after high seasonal streamflows, then repeat sampling should be conducted at that same time of year to determine trend. Monitoring later in the season or when vegetation has been grazed may make plant identification more difficult, but because this is when the data helps answer typical issues with livestock grazing, the procedures described in this protocol should be done at the time the information will be most useful for evaluation and interpretation. Woody species utilization data cannot be gathered until the annual growth of new leaders on woody species begins along the greenline.

It is also important for users to carefully consider the objectives and purpose for gathering the monitoring data in determining the most appropriate time to monitor. For instance, since streambank alteration can influence streambank stability, long-term streambank stability conditions would be most appropriately and accurately monitored prior to livestock use and after the stream has recovered from the previous year's disturbances. In addition, monitoring greenline vegetation on a DMA that has received significant alteration will cause the greenline to be located farther up the bank and likely in another plant community than if done prior to grazing or after recovery the following year. Users need to understand these relationships and clearly determine why they are collecting data and how they are to be used.

Short-term indicator data may be collected in a different season than the trend data; however, short-term data should be collected when it is appropriate, typically immediately following livestock use. Data may be collected prior to livestock grazing so that other uses, e.g., wildlife, wild horse, or recreation impacts, may be estimated. If the management prescription requires a certain amount of residual vegetation remaining to protect streambanks during high winter or spring flows, monitoring should be done after the growing season has ended and livestock have been removed from the area.

3. Determine How Often to Monitor: Long-term (trend) monitoring data should be gathered at 3- to 5-year intervals. The first repeat monitoring following adjustments in management should be done 2 or 3 years after establishment. Riparian areas are resilient and vegetation usually responds quickly following management adjustments. Consequently, management can be evaluated early, making it possible to establish a trend. More frequent trend monitoring establishes a more definitive trend curve. However, following the initial analysis and interpretation, the long-term monitoring cycle may be extended to every 3 to 5 years. In some cases, the period may be extended because of slower recovery rates. Ten years should be the longest interval used on any site.

Short-term monitoring data may be gathered annually. Answers to specific questions, e.g., livestock versus elk streambank alteration, may require monitoring some indicators two or more times during the year.

III. LOCATE THE GREENLINE

Locating the greenline is key to using the MIM protocol. Most of the monitoring procedures in this protocol require the identification of the greenline as a reference point for collecting sampling data.

A. The Significance of Monitoring at the Greenline

The "greenline" as defined by Winward (2000) is the "first perennial vegetation that forms a lineal grouping of community types on or near the water's edge." Given the annual scour of the stream, this line often forms at or just below the bankfull level of the stream channel. The greenline often coincides with the presence of water in the plant rooting zone, which allows for the growth of robust, hydrophytic plant species with deep roots that resist the erosive forces of the stream (Winward 2000). Plant species distribution in arid and semiarid ecosystems is largely controlled by the availability of water from ground water or instream sources (Jewett et al. 2004). As stated by Cagney (1993):

> Typically, a soil moisture gradient is exhibited when moving away from the channel in a riparian area. In a trend transect placed in a typical western floodplain, a different soil moisture could conceivably be encountered at each plot. Attempting to average the vegetation found in these divergent plots into a single set of data can be problematic. The greenline is a point of reference that minimizes problems associated with changing moisture gradient.

The greenline represents a particularly critical location for monitoring. Minimizing the problems associated with the moisture gradient allows more efficient monitoring and more effective results and best reflects influences of grazing and other disturbances. Because changes occur here more rapidly, the land manager can make an early evaluation of effects (Winward 2000). Livestock and other ungulates are attracted to streamside areas, which can affect the condition of streamside vegetation, streambanks, and the streambed (Wyman et al. 2006; Clary and Kruse 2004; Platts 1991). Not only is the riparian ecosystem affected, but the channel and stream habitat are also strongly influenced by actions at this location. Changes to riparian vegetation at the greenline may also result in: 1) accelerated streambank erosion, 2) increased width/depth ratios, 3) altered channel patterns, 4) increased sediment supply, 5) decreased sediment transport capability, and 6) damaged fisheries habitat (Rosgen 1996).

The formation of the greenline is strongly influenced by the flood regimes of the stream and sometimes occurs at the bankfull level. The shape of the channel cross section reflecting the bankfull level is related to the annual flood level. As stated by Rosgen (1996):

> The term 'bankfull' was originally used to describe the incipient elevation on the bank where flooding begins. In many stream systems, the bankfull stage is associated with the flow that just fills the channel to the top of its banks and at a point where the water begins to overflow onto a floodplain.

The energy of the stream inside the active channel tends to peak at bankfull discharge, causing the formation of the trapezoidal- or rectangular-shaped channel. Vigorously growing vegetation at the channel margin is constantly attempting to expand in distribution, even inward of the channel, but the flood zone or zone of semiconstant watering inhibits or limits such encroachment. This process contributes to formation of the greenline. The flood that occurs, on the average, about once every 1.5 years has been equated with the bankfull channel (Dunne and Leopold 1978; Rosgen 1996). It is the frequency of this flood regime that allows for doing the work of shaping the channel and controlling the advance of streamside vegetation. Stream channels that are associated with highly variable streamflows within season and from year to year, such as arid channels in the desert Southwest, and that often discharge high volumes of sediment, may form complex greenlines. These greenlines vary in elevation along the margins of the channel and are difficult to sample.

The greenline was selected as a monitoring location because unpublished data (Henderson 2003) suggest that observers more consistently identified the greenline than the bankfull position on the streambank, thus improving the precision. These data also correspond to the authors' experiences.

B. Using Rules to Establish the Greenline Location

1. Defining the Greenline: The greenline is a linear grouping of live perennial vascular plants, embedded rock, or anchored wood above the waterline on or near the water's edge (adapted from Winward 2000). It often forms a relatively continuous line of perennial vegetation adjacent to the stream (Cagney 1993). However, the greenline can also be patches of vegetation on sandbars and other areas where new vegetation is growing. Individual linear groupings are considered part of the greenline when they meet the rules described in this chapter. The greenline can also be composed partially or entirely of embedded rock and/or anchored wood. The greenline is commonly located at the edge of the floodplain or at the lip of the first bench above the water line. For entrenched streams, the greenline may be located above the floodplain on a terrace (Winward 2000). In these cases, the greenline may include, or be limited to, nonhydric species, i.e., upland species. See appendix A for greenline examples.

2. Placing the Monitoring Frame on the Greenline: A frame is placed on the greenline to designate the observation point. The monitoring frame consists of two side-by-side, 20- by 50-cm Daubenmire quadrats (figure 2), which are commonly applied to vegetation sampling. The center bar, or longwise orientation of the frame is placed on the greenline (figure 3). Elzinga et al. (1998) stated: "It is best if the quadrat length (i.e., the length of the long side of the quadrat) is longer than the mean distance between clumps." Because streamside vegetation is usually high in spatial density, a quadrat plot 50 cm in length is adequate to avoid empty spaces between clumps and small enough to be reasonably efficient. Details for constructing the frame are found in appendix C.

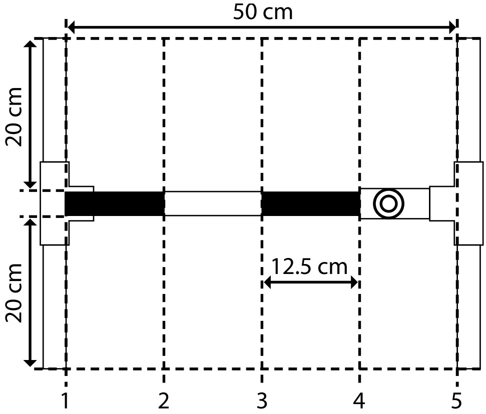


Figure 2. Multiple indicator monitoring frame. Based on field experience, this is the preferred frame configuration. It is light, easy to carry, and easy to manipulate in shrub type vegetation. Dashed lines are apparent but not part of the actual frame. Observers must be careful to extend these lines within the confines of the frame.

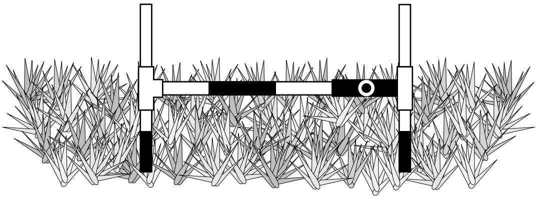


Figure 3. Center bar placement. The monitoring frame is placed with the center bar on the greenline.

The greenline plot is located by moving the monitoring frame in a perpendicular direction from the streamflow at the water's edge up the streambank to the location closest to the channel that meets the greenline rules described in the following section (within 6 m of the water's edge). The center bar of the monitoring frame is placed along the edge of the perennial vegetation, embedded rock, and/or anchored wood or at the base of the overstory shrubs or trees.

To meet the greenline rules, the monitoring frame may be rotated up to 75° from parallel to the streamflow until the cover rules are met (figures 4 and 5).

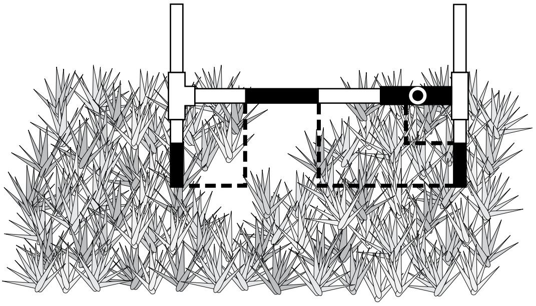


Figure 4. The frame is placed along the line of vegetation closest to the stream. The center of the frame is placed along the edge of the perennial vegetation, rock, or wood. If there is a bare patch within the frame, as shown in this diagram, the frame is rotated as shown in figure 5.

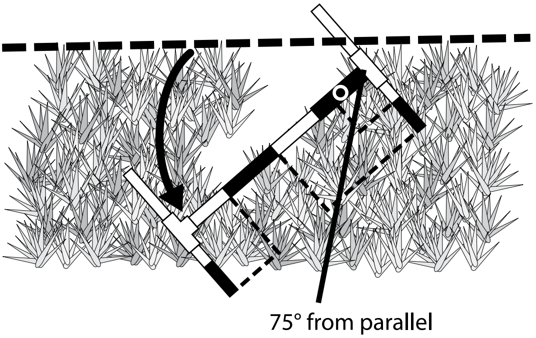


Figure 5. Either end of the frame may be rotated away from the stream until the cover requirements are met. The rotation should not exceed 75° from parallel with the streamflow.

3. Greenline Rules:

a. Perennial Herbaceous Vegetation, Shrub/Tree Seedlings, Embedded Rock, Anchored Wood: The greenline can be comprised of any combination of perennial herbaceous vegetation, shrub/tree seedlings, embedded rock, or anchored wood provided that there are **no patches of bare ground (rocks smaller than 15 cm are considered bare ground), litter, or nonvascular plants greater than 10 by 10 cm within the plot:**

1) Perennial Herbaceous Vegetation, Shrub/Tree Seedlings: There must be at least 25 percent foliar cover of live perennial herbaceous vegetation and/or shrub/tree seedlings rooted in the plot. Foliar cover (live plant parts, stems, and leaves over the ground) is the shadow cast if the sun was directly overhead. Small openings in the canopy or overlap within the plant are excluded. Shrub and tree seedlings are defined as woody plants less than 0.5 m tall.

2) Embedded Rock: The greenline may include rock that is at least 15 cm in diameter and at least partially embedded in the streambank with no evidence of erosion behind it, talus slopes, and bedrock. **Rock must be above the scour line and not in the active channel** (see appendix A, figures A20 and A21).

3) Anchored Wood: The greenline may include logs or root wads that are anchored into the streambank and large enough such that high flows are not likely to move them. There should be no evidence of erosion behind them. **Wood must be above the scour line and not in the active channel** (see appendix A, figures A21 and A22).

b. Overstory (Young and/or Mature Shrubs or Trees): If young or mature woody plants are located closer to the water's edge than qualifying perennial herbaceous vegetation, rock, or wood (as described above), the greenline is located at the base of young or mature shrubs or trees as shown in figure 6. Young and mature shrubs and trees are defined as woody plants at least 0.5 m tall. Foliar cover of young and mature shrubs and trees is not considered for identifying the greenline. When there is no understory beneath the shrub/tree canopy, the greenline is located at the rooted base of the shrubs or trees or beneath the shrub/tree canopy along a simulated line connecting the rooted base of adjacent shrubs and/or trees roughly parallel to the stream (see figures 7 and 8 and appendix A, figures A10 and A11).

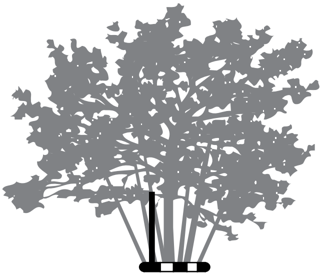


Figure 6. The monitoring frame is placed at the base of a mature woody plant.

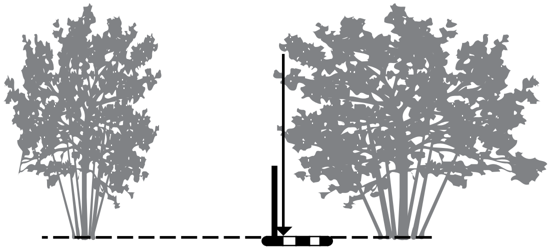


Figure 7. When there is woody overstory and no understory, and if the shrub or tree canopy is directly overhead, the frame is placed on a simulated line connecting the rooted base of the shrubs or trees (on the stream side of the shrubs or trees).

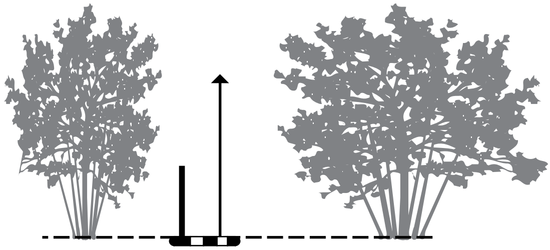


Figure 8. When there is no canopy cover above the line joining the bases of woody species, the frame should be moved away from the stream until the greenline is reached or the distance from the stream is 6 m.

c. Exposed Roots: Exposed live shrub or tree roots above the scour line of the stream are part of the greenline (see appendix A, figure A16).

d. Flooded Greenline: Avoid sampling when the greenline is flooded during high streamflow (see appendix A, figure A12).

e. Perennial Vegetation Growing in Water: Some perennial vegetation, e.g., spike rush, sedges, rushes, or willows, may grow in the margins of the stream and in slow backwaters or even inside the wetted channel at seasonal low flow. When this occurs, **the greenline will be at the edge of the water** (see appendix A, figures A13 and A14).

f. Plants Occupying the Entire Wetted Channel: For dewatered channels and channels with very low flows, if the vegetation occupies the entire width of the channel, **the greenline is at the deepest part of the channel** (see figure A15).

g. Floating Plant Species: Some species that commonly float on or are submerged in the water have minimal root systems and are ***not*** part of the greenline. These species may include, but are not limited to, whorlgrass or brookgrass (*Catabrosa aquatica*), white water crowfoot (*Ranunculus aquatilis*), watercress (*Rorippa nasturtium-aquaticum*), American speedwell (*Veronica americana*), water knotweed (*Polygonum amphibium*), and other species that have similar rooting characteristics (see appendix A, figures A17, A18, and A19).

NOTE: When whorlgrass or brookgrass (*Catabrosa aquatica*) is rooted above the water level on the streambank above seasonal low waterflow, it is considered part of the greenline and should be recorded in the greenline vegetation composition.

h. Detached Blocks of Vegetation: Blocks of vegetation detached from the streambanks (slump blocks) are not the greenline. When deep-rooted hydric vegetation covers the block from the water's edge to the terrace wall, creating a new floodplain (false bank), the greenline is the edge of the vegetation along the stream (see appendix A, figures A23, A24, and A25). To be detached or separated from the bank, a block or section of streambank must have slipped down or broken away from the bank wall so that there is less than 25 percent foliar cover of perennial vegetation in the area between the block and the bank wall.

i. Islands: Islands are defined as areas surrounded by water at summer low flow or bounded by a channel that is scoured frequently enough to keep perennial vegetation from growing. **The greenline follows the outside channel on each side of the island and does not cross onto an island** (see appendix A, figures A26, A27, and A28).

j. No Greenline Present: When the greenline is not present within **6 m from the water's edge**, the greenline is considered absent at that plot (NG is recorded in the vegetation composition column in the Data Entry Module or on the MIM Field Data Sheet shown in appendix B). The monitoring frame is then placed on the edge of the first bench above the waterline, and the other indicators are read (e.g., streambank alteration, streambank stability, etc.). If there is no bench present, the frame is placed at the position on the streambank 6 m from the water's edge, and the other appropriate indicators are read (see appendix A, figure A29).

In instances where the waterlines are less than 6 m apart due to the presence of a sharp meander bend with a peninsula between them, and the greenline rules cannot be met between the waterlines, the frame is placed at the top of the peninsula.

IV. MEASURE INDICATORS USING SYSTEMATIC PROCEDURES AND METRICS

This chapter provides definition and context for the monitoring indicators and their associated metrics and describes how to measure each. As used in this document, a metric is defined as a system of measurement that facilitates the quantification of a monitoring characteristic. For example, greenline composition is a monitoring indicator that is measured in the field. Greenline vegetation ecological status is a metric that quantitatively describes the seral status of that vegetation.

A. Systematic Procedures

Step 1. Develop a Species List: Prior to data collection, do a reconnaissance of the greenline vegetation within the DMA and record species and species codes that may be found in the Data Entry Module. If the code is not in the Data Entry Module, use the official plant codes in the PLANTS Database (USDA, Natural Resources Conservation Service 2010). Collect plants for identification if not known in the field.

Step 2. Determine the Appropriate Sampling Interval: Random systematic sampling along the greenline and within the channel allows for even spacing and precise estimation of vegetation and site characteristics (Elzinga et al. 1998).

The sampling interval is the distance between plots and should be large enough to achieve the desired precision. An interval of 2.75 m provides 40 plot locations on each side of the stream (at least 80 total plots in the DMA) in a 110-m DMA. This frequency provides a sample size large enough to estimate the mean within 10 percent of the true mean as described in table F6 (appendix F) for most of the streams evaluated in the MIM tests. When the site is very complex or highly variable, the interval may be shortened to increase the number of samples. For example, the interval may be shortened to 2 m providing 55 sample locations on each side of the stream. When the DMA reach is longer than 110 m, divide the total DMA length by 40 to obtain the sampling interval.

Step 3. Measure the Sampling Interval: The sampling intervals may be measured or paced. A typical 2-m rod is useful for measuring the interval. When pacing the sampling interval, the user determines the length of his/her step by marking a distance, usually 30 m, and counting the number of steps over the selected distance. This step length and number of steps are then used to pace the sampling interval.

Step 4. Establish the Location of the First Sample: Pick a random number between 1 and 10. Beginning at the lower reach marker on the left-hand side (looking upstream), take that number of steps within the stream channel. Turn and face the left-hand bank and proceed perpendicularly to the stream until the greenline is encountered. Place the monitoring frame with the center bar oriented along the greenline (figure 9).

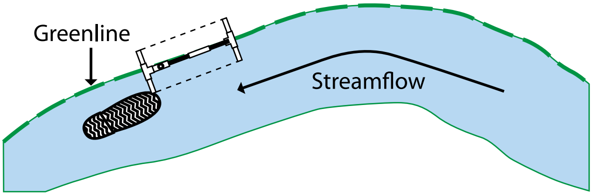


Figure 9. The first sample. The monitoring frame is placed at the end of the toe with the center of the frame along the greenline.

Monitoring of indicators should be completed in the following order to minimize movement of the frame: greenline composition, woody species height class, streambank alteration, streambank stability and cover, stubble height, GGW, woody species age class, woody species use, and substrate. All data except the residual pool depth and pool frequency are recorded at this location, and subsequent plots are spaced at equal intervals from this first sample.

Step 5. Sample the Entire DMA: Monitor along the greenline at the appropriate sample interval to the end of the DMA. The minimum number of samples on each side of the stream is 40. After sampling the last plot on the left-hand side of the stream, measure or pace the distance from the last sample location to the end marker, cross the stream, and from the marker, continue measuring or pacing until the plot interval is reached. For example, if the sample interval is 2.75 m and it is 1 m from the last sample location to the stake, cross the stream beginning at the marker, measure 1.75 m and place the monitoring frame on the greenline. Repeat the procedure down the right-hand side (looking upstream) using the same interval (2.75 m) to the end marker. The **entire length** of DMA on both sides of the stream is sampled (figure 10).

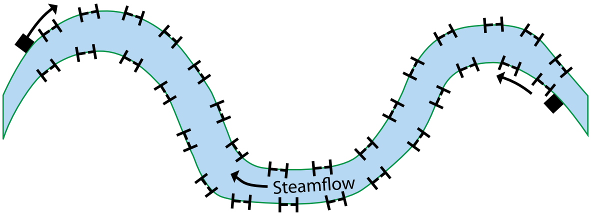


Figure 10. The DMA. A random systematic sampling design is used for monitoring. The first plot location is randomly selected and the remaining samples are regularly spaced along the reach. Black squares delineate DMA markers.

Step 6. Ensure the Appropriateness of the Sample Size: After completing both sides of the stream, the sample size estimator at the top of the "DMA" worksheet in the Data Entry Module may indicate that more samples are needed to achieve the desired level of precision. Calculations for the sample size estimator are described on the "Stats" worksheet in the Data Entry Module. They require the calculation of a standard deviation and thus apply only to quantitative indicators that produce a statistical mean (streambank alteration, stubble height, greenline-to-greenline width, woody species age class, and woody species use). The default confidence level is set at 95 percent, and the level of precision varies as shown on the "Header" worksheet in the Data Entry Module. These levels can be adjusted by the user to derive the desired confidence and precision; however, the default precision levels should be adjusted only after careful consideration because the precision levels provided in the module are based on confidence interval widths from field tests (see appendix F for additional details).

To determine the number of additional samples needed, subtract the number of samples taken from the number of samples indicated on the sample size estimator for each indicator not meeting the desired sample size. Divide the DMA reach length by the number of samples for the indicator needing the most additional samples. For example, if the sample size estimator indicates an additional 10 samples are needed for an indicator, and the DMA length is 110 m, divide 110 by 10, which equals 11 m. Beginning at the lower reach marker (left-hand side looking upstream), measure or pace 11 m upstream, place the monitoring frame on the greenline on the left-hand bank. Sample all indicators not meeting sample size criteria. The next sample site will be 11 m upstream on the greenline on the right-hand bank. Continue sampling alternating streambanks to the upstream marker. Sample all the necessary indicators along the entire reach, even if the sample size criteria are met before reaching the end of the DMA.

B. Indicators

1. Stubble Height:

a. Purpose: Stubble height is a measure of the residual height of key herbaceous vegetation species remaining after grazing. The amount of foliar cover remaining is important for keeping plants healthy, maintaining or promoting strong root systems, protecting streambanks from erosion, slowing water during high streamflows, and building floodplains (Clary and Webster 1989). The measurement may be used in at least two ways: first, to determine when livestock should be moved from the riparian area, often called trigger monitoring, and second, at the end of the grazing season and growing season to help determine cause-and-effect relationships between livestock grazing and stream-riparian conditions and whether livestock grazing management changes may be needed the following year.

b. Background: The stubble height procedure is described in *Utilization Studies and Residual Measurements* (USDI, BLM 1996b). The procedures in this protocol were modified for use with a quadrat in the systematic random sampling design for locating quadrats. Because many of the important riparian graminoid species are rhizomatous, they grow in dense matlike patches of vegetation making it difficult to identify individual plants. Therefore, a 3-inch (8-cm) circle of vegetation is used rather than an individual plant.

Within the randomly located quadrat, the number of plants measured is limited to key species, which are plants that are important in the plant community, are relatively palatable to livestock use, and serve as indicators of change.

c. Assumptions and Limitations: Stubble height has been widely used to measure livestock vegetation use in riparian areas (Clary and Leininger 2000). It allows a large number of samples to be collected in a short period of time. It can be used as a trigger for moving livestock to another grazing unit or as an indicator of the amount of use after grazing (University of Idaho Stubble Height Review Team 2004). Stubble height is not a substitute for vegetation condition or trend; however, it does provide information that may be used to determine the degree to which livestock grazing is influencing the achievement of objectives.

Stubble height is not an appropriate measure on streams that are dominated by woody species, boulders, or bedrock and should not be used where herbaceous species are infrequently scattered along the DMA.

d. Relationship to Other Indicators: Stubble height data can be enhanced when analyzed with percent of livestock use (not in the MIM protocol), woody species use, and streambank alteration to estimate levels of grazing intensity during the current grazing season. Coupled with other short-term and long-term monitoring indicators, stubble height may be used to develop relationships between condition and trend and livestock grazing management. Stubble height alone does not provide adequate information to develop a relationship between livestock grazing and vegetation conditions on the streambank. Commonly, streambank disturbance, measured by the streambank alteration procedure, is the most important factor relating to streambank stability conditions.

e. Procedure:

Step 1. Determine Key Species: An interdisciplinary team should select the key species, as defined earlier, prior to monitoring. Deeper rooted plants, such as hydric species, are preferred because of their contributions to stability. If palatable hydric graminoids are severely lacking or absent, palatable mesic graminoids are chosen. Measure the stubble height of each key species occurring within the monitoring frame. More than one key species may be used if necessary.

Step 2. Select Plants: After placing the frame, select the key species that occur nearest the handle of the frame (figure 11). Most riparian key species grow tightly together, forming dense mats with little distinct separation of individual plants. As a result, the sampling method uses a 3-inch-diameter circle of the vegetation for a single species (figure 12).

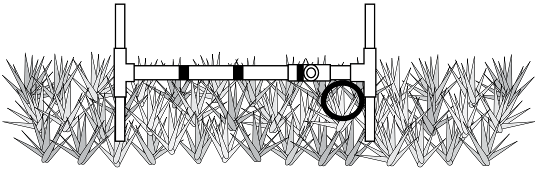


Figure 11. Residual vegetation height is measured within a 3-inch-diameter circle at the back right-hand corner of the quadrat nearest the frame handle.

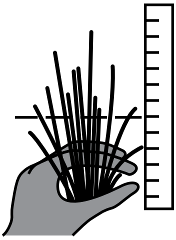


Figure 12. Stubble height is measured by forming your hand into an approximate 3-inch-diameter circle, grasping the vegetation, and determining the average leaf length.

When the key species does not occur in a mat near the handle of the frame but as an individual plant or several individual plants less than 3 inches in diameter, select the key species plant within the plot that is nearest the handle (see figure 13). Measure the average height of all the leaves of the plant(s).

When a key species does not occur within the quadrat, **leave the cell blank** (on the MIM Field Data Sheet or in the Data Entry Module).

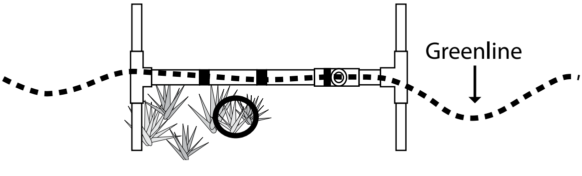


Figure 13. When key species plants are not in the corner by the frame handle, select the key species plants nearest the handle. Identify the plant and measure the average leaf height of all key species plants rooted within the circle.

Step 3. Measure Key Species: Using the frame handle (or a ruler) with 1-inch (or 2-cm) increments, measure the average leaf length of the vegetation within the circle (figure 11 and 13) and round it to the nearest inch (or 2 cm). Grazed and ungrazed leaves are measured from the ground surface to the top of the remaining leaves. All leaves within the circle should be lifted to determine their length. Account for very short leaves as well as tall leaves. **Do not measure seed stalks (culms)**. Determining the "average" residual vegetation height will take some practice. Be sure to include all of the key species' leaves within the sample. The easiest method of doing this is to grasp the sample, stand the leaves upright, and then measure the average height (figure 12).

f. Timing:

1) Pregrazing Monitoring: Stubble height monitoring may be done throughout the season depending on the questions that need to be answered. If there is a concern regarding the amount of utilization by elk, domestic or wild horses, or other large herbivores, monitoring may be done prior to livestock entering the grazing unit.

2) Monitoring During Grazing: Determining when livestock should be moved to meet a grazing prescription, as described previously, is done while livestock are still in the area and when the vegetation is close to reaching the prescribed height.

3) Postgrazing Monitoring: The most common time to measure stubble height is at the end of the grazing period and the growing season (called postgrazing monitoring) to provide some of the information necessary to develop relationships between the condition and trend and livestock grazing.

g. Metrics: Stubble height data are summarized using the following metrics:

- ***Average (Mean) Stubble Height of All Key Species:*** This metric is the average of all stubble height measurements made at the DMA (see Data Analysis Module – "Summary" worksheet).

- ***Median (Midpoint) Stubble Height of All Key Species:*** The median stubble height value taken from all measurements at the DMA (see Data Analysis Module – "Summary" worksheet).

- ***Average (Mean) Stubble Height of the Most Dominant Key Species:*** This metric represents the average of all stubble height measurements for the key species most frequently encountered at the DMA (see Data Analysis Module – "Graphs" worksheet).

- ***Average Stubble Height for Each Key Species Measured:*** This metric represents the average for each key species. It is provided because the most palatable species may not be the most frequently encountered at the DMA (see Data Analysis Module – "Graphs" worksheet).

Stubble heights are scaled measurements and sometimes fit a normal probability distribution. When data are skewed, as is often the case for combined stubble height for all species, a log transformation may be used to normalize the distribution. Stubble heights for individual species, particularly those that are palatable, commonly fit normal probability distributions.

2. Streambank Alteration:

a. Purpose: The physical alteration of streambanks by animals can degrade the integrity of stream systems. Platts (1991) observed that alteration may negatively affect water quality and aquatic habitat. Trampling of streambanks by livestock may result in an increase in stream width, making the stream channel wider and shallower (Clary et al. 1996). As a result, water temperatures may increase from increased exposure to solar radiation; sediment is deposited within the channel rather than on the streambanks; streambank erosion increases; and the water storage capacity of the streambanks decreases, forcing streamside plants to shift from willows and sedges to drier site species with low root density (Bengeyfield 2006). All of these changes combine to result in the loss of habitat for aquatic species (Platts 1991).

Similar to stubble height, streambank alteration is an annual or short-term indicator of the effect of grazing impacts on long-term streambank stability. As such, it can be used as a tool to assess grazing intensity and to determine when such intensity may be excessive. It can also be used to help determine cause-and-effect relationships between livestock grazing and stream-riparian conditions and whether livestock grazing management changes may be needed the following year.

The importance of streambank alteration as a short-term indicator has only recently emerged in the literature (Heitke et al. 2008). In measurements of forage utilization, stubble height, and streambank alteration at 14 stream reaches in southwestern Montana, Bengeyfield (2006) found: ". . . the only streams that showed significant improvement were those where the streambank alteration levels were met. Neither a forage utilization of 45 percent nor a stubble height at 4 inches initiated the upward trend in stream channel shape that is necessary to achieve riparian function."

b. Background: Stream channels are naturally dynamic with varying rates of annual disturbance, but streams are constantly striving to achieve stability and to maintain channel capacity and competence (Leopold et al. 1992). As a result, streams have the ability to repair a certain degree of streambank disturbance each year. Several factors, including stream gradient or slope, streambed material composition, streambank soil composition, vegetation cover and type, channel geometry, flow rate and timing, and frost action determine the amount of alteration that streambanks can repair each year. As stated by Clary and Kruse (2004): ". . . concentrated impacts under rotation systems can cause sufficient woody plant or streambank damage in a single season or year that recovery might take several years. Therefore, the best approach is to limit grazing stress to the site's capability for annual recovery." This capability for annual recovery would be evaluated by measuring both streambank alteration and streambank stability at the DMA as described under "Relationship to Other Indicators."

Heitke et al. (2008) evaluated several methods of monitoring streambank alteration along the greenline using data collected in Montana in 2003 and 2004. The greenline (GL) method used a line intercept procedure that records presence or absence of disturbance. A sample line was 92 cm long, centered on the greenline. The line was placed perpendicular to the stream channel at the point of the toe of the observer. Each line was recorded as altered or not altered. A line was considered altered if current year's disturbance occurred along any part of the line. A sample was recorded at each step along the greenline. The amount of alteration was calculated by dividing the number of lines with alteration by the total number of samples. Results were expressed as a percent.

The greenline precise (GLP) method was exactly the same as the GL method, except the length of each disturbance along the line was measured. For example, at the first sample location, 20 cm of disturbance was measured and recorded along the 92-cm line. This procedure was repeated on both sides of the stream making an observation and measurement at each step. The total length of disturbance measured was divided by 92 times the number of samples taken. The product was expressed as a percent.

Heitke et al. (2008) also discussed the bankfull (BF) method. This method was a precursor to the MIM protocol and was later modified to use the greenline rather than the bankfull line because observers more often agree on the location of the greenline than the bankfull line (Henderson 2003). The monitoring frame was further modified to its present configuration to facilitate measuring other indicators. The frame was shortened to 50 cm, and to prevent double counting of average sized hoofprints, the number of lines was reduced to 5, spaced at approximately the average diameter of the hoofprint. The width of the frame was increased to allow using 20- by 50-cm Daubenmire plots on each side of the center bar.

However, the BF method was not evaluated in Heitke et al. (2008). The BF method also uses line intercept. It differs from the previous two methods by using a 30.5- by 61-cm monitoring frame. The frame was similar to the one described in figure 2. The width evaluated was about 15 cm either side of the center bar. The center bar was placed at the bankfull line. Ten lines were projected perpendicular to the center bar and alteration was recorded when any of the lines intersected current year's disturbance.

Heitke et al. (2008) assessed variability among observers for the different protocols described above. They used the standard deviation between observations made by the same or different observers. The GLP had the lowest overall observer variability as measured by the standard deviation (4.7, with coefficient of variation or CV = 56), followed by GL (6.3, CV = 20), and BF (8.1, CV = 35). The authors conducted 35 tests for observer variability on the MIM streambank alteration procedure, which is refined from the BF procedure analyzed by Heitke et al. (2008). The standard deviation between observers for the MIM tests was 4.3 and the CV was 22.7. The CV is a dimensionless index of variability between and among observers' repeated observations and is represented by the standard deviation divided by the mean.

The procedure described here estimates the amount of streambank alteration along the greenline as a result of large herbivores (e.g., cattle, horses, sheep, bison, elk, and moose) walking along or crossing the greenline during the current grazing season.

The part of the streambank that is measured using this procedure is a plot 50 cm long and 42 cm wide (two Daubenmire plot widths plus the 2-cm-wide center bar), centered on the greenline. This part of the streambank focuses the observation where stability is most affected by the erosive effects of water (see appendix D).

c. **Assumptions and Limitations:** There are five cross-plot lines on the sampling frame used to detect and record occurrences of alteration. These lines are perpendicular to the center rib of the frame and extend away from it on each side.

As the center rib is placed on the greenline, intercept lines extend 20 cm into both the vegetated and nonvegetated side of the greenline. If more than one alteration intercepts this line on either or both sides of the center rib, a value of 1 is recorded in the Data Entry Module or on the MIM Field Data Sheet.

The number of alteration intercepts or "hits" is limited to five per sample because: 1) alteration occurs primarily on the nonvegetated side of the greenline, and double-counting the vegetated side would underestimate the frequency of disturbances along the greenline; and 2) the spacing between intercept lines approximates the diameter of a hoofprint, which minimizes double-counting of single hoof impressions.

Trampling impacts must be the ***obvious*** (i.e., easily seen, clear to the eye, not to be doubted, or plain) result of current season use. "Obvious" streambank alterations are defined as those that are readily observed from no closer than approximately 2 feet from the streambank. In general, these are impacts that are evident without kneeling close to or lying on the ground.

The streambank alteration procedure described here is an intercept procedure recording presence/absence of current year's disturbance along the greenline. It is not a measure of the percent of the area of streambank altered, but rather an estimate of the percent of the length of bank altered along the greenline based on the presence or absence of a hoofprint(s) intercepting one (or more) of the five lines within a plot. This procedure samples only that part of the streambank associated with the greenline, often at the top of the streambank, and only within a 42- by 50-cm plot. The streambank may be wider or narrower than the width of the plot.

The monitoring frame is 42 by 50 cm (or 2100 cm^2) and the average cattle hoofprint is 12 cm by 17 cm or 208 cm^2. Therefore, one hoofprint in the frame represents approximately 10 percent of the area within the frame that is altered. The width of an average hoofprint oriented along the greenline is 12 cm, so its length along the greenline is 12/50 cm or about 24 percent. Because the MIM protocol uses a line intercept approach with the intercept lines spaced slightly wider than the average hoofprint, that same hoofprint would intercept one of the five lines and be recorded as 20 percent alteration for that plot. Thus alteration using the MIM protocol more closely approximates length of greenline altered, not the area of the plot altered. The advantages of this method over others is that it is more efficient and precise and has been widely tested.

The authors measured the dimensions of actual cattle hoofprints and shears where they were clearly identifiable. Using simulations that randomly selected these measured prints and randomly placed them on the plot at varying numbers and locations, a relationship was established between true streambank alteration and MIM estimates. The MIM protocol closely estimates the percent of greenline length altered (percent greenline length altered = .914 times MIM alteration + 5 percent, $R^2 = .85$). There was a weaker relationship to the area of plot altered (percent plot area altered = .32 times MIM alteration + 3 percent, $R^2 = .55$). Thus, if the MIM alteration is observed at 20 percent, the simulations predict the percent of greenline length altered to be 23 percent, and the area of plot altered to be 9 percent. The plot area in these simulations included both the vegetated and nonvegetated sides of the greenline. The majority of streambank alterations are typically observed on the nonvegetated side of the plot. If only the nonvegetated side of the plot is used to estimate plot area from these simulations, the relationship between MIM alteration and plot area altered is closer (20 percent MIM alteration with 18 percent plot area altered). Note, however, that as percent alteration increases, the ratio of MIM alteration to plot area altered also increases (e.g., 60 percent MIM alteration equates to 44 percent plot area altered using the nonvegetated plot). Note also that the ratio of MIM alteration to length of greenline altered does not change dramatically (e.g., 60 percent MIM alteration equates to 60 percent length of greenline altered). Thus, the MIM protocol tends to overestimate plot area altered but more closely estimates length of greenline altered.

d. Relationship to Other Indicators: Because streams have the ability to repair a certain amount of streambank alteration after disturbance, it is important that the intensity of disturbance, or streambank alteration, be less than the amount of streambank stability repair. The amount of repair can be estimated by measuring the recovery after disturbance. To estimate the amount of repair after disturbance, both streambank alteration and streambank stability would be measured immediately after grazing and then again just before the next grazing period. This would allow an estimate of the change in streambank stability during the "off" season, reflecting natural processes of streambank recovery, along with natural sources of streambank alteration (e.g., wild ungulates and stream flooding).

The most effective method of determining the potential streambank stability repair rate is to compare measurements of streambank stability along the stream reach of interest with a comparable stream reach within a reference area. Changes in stability caused by flooding, ice scour, and other natural effects can then be factored into the relationship between streambank alteration and streambank stability.

e. Procedure:

Step 1. Locate the Intercept Lines: This procedure uses the entire 42- by 50-cm monitoring frame. Five lines are projected across the frame perpendicularly to the center bar of the frame (figure 14).

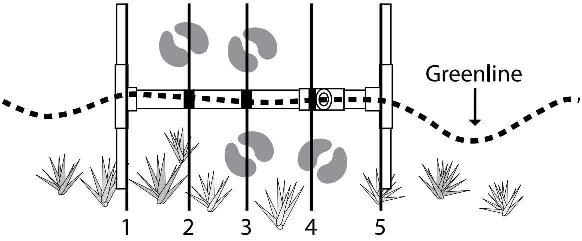


Figure 14. A monitoring frame with five lines projected on the plot. There are four hoofprints on this plot. Lines 2 and 4 each intersect one hoofprint. Line 3 intersects two hoofprints. Three lines intersect hoofprints, so the number of alterations on this plot is recorded as a 3.

Step 2. Count the Lines that Intercept Alteration: Look down at the entire frame and determine the number of lines within the plot that intersect streambank alteration (see appendix D). The streambank is considered altered when:

- Streambanks are covered with vegetation and have hoofprints that depress the soil and expose bare soil at least 13 mm deep (measured from the top of the displaced soil to the bottom of the hoof impression).
- Streambanks exhibit broken vegetation cover resulting from animals walking along the streambank that have a hoofprint at least 13 mm deep.
- Streambanks have compacted soil caused by animals repeatedly walking over the same area even though the animals' hooves sink into and/or displace the soil less than 13 mm.

Step 3. Record the Number of Lines that Intersect Streambank Alteration: Record only one occurrence of alteration, trampling, or shearing per line. **Record only the current year's streambank disturbance—disturbance features that are obvious (old features tend to be nondistinct).** Follow these guidelines when determining which number to record:

- When there is a vertical or near-vertical wall, pace in the stream or along the greenline on top of the terrace, and place the center of the frame along the greenline. Record only direct alteration occurring on the vertical wall (hoof shear), on the streambank, and/or at the base of the vertical wall as viewed down the slope within the plot (see appendix D, figure D5).

- Hoofprints or trampling on streambanks with fully developed, deep-rooted hydric vegetation (e.g., *Carex* spp., *Juncus* spp., and *Salix* spp.) is not recorded as alteration unless plant roots or bare soil is exposed. Hoof shearing along the streambank is considered alteration.

- Compacted livestock trails on or crossing the greenline, that are the obvious result of the current season's use, are counted as trampling (see appendix D, figure D3).

- When there is no greenline identified within 6 m from the water's edge and "NG" (no greenline) is recorded, the frame is placed on the first slope break (bench) above the waterline for measuring the streambank alteration (and other appropriate indicators). If no bench is present, place the frame at the position on the streambank 6 m from the water's edge.

This process is repeated at the predetermined interval on each side of the stream.

f. Timing: Streambank alteration is measured annually after grazing. It is most effective if measured as soon as possible after livestock have been moved from the area so that alteration by livestock can easily be distinguished from natural disturbances by wild ungulates. It may be used during the grazing season to trigger a need to move livestock out of the pasture. A target or criterion for streambank alteration could be established as a trigger to move or as an end-of-season indicator to evaluate the effectiveness of the management prescription. As indicated, streambank alteration may also be measured, just prior to livestock entry into the pasture, to isolate the added effect of wild ungulates. Streambank alteration may also be measured in rest years, when livestock are not scheduled to be in the pasture, to evaluate other sources of natural disturbance or to assess alterations resulting from livestock trespass.

g. Metrics: The following metric is used to summarize streambank alteration data:

- ***Percent Alteration:*** Since streambank alteration is estimated from 400 individual observations along the greenline (if 80 plots are used), streambank alteration is a metric that represents the percent of hits (or lines intercepting hoofprints or shears) lineally along the greenline.

The metric is calculated as the average number of hits (intercepts of alteration) per plot, expressed in a percent. This is the same as tallying the total number of hits for all plots, dividing by the total number of plots to obtain an average number of hits, and then dividing by 5 to obtain percent alteration. Thus if a survey resulted in 100 hits from 80 plots, 100 divided by 80 and then divided by 5 equals 0.25 (25 percent).

In a typical survey, most plots contain 0, 1, or 2 hits. For that reason, streambank alteration data tend to be distributed with a distinct skew to the left and therefore do not fit a normal probability distribution (see Data Analysis Module – "Data Summary" worksheet).

3. Woody Species Use:

a. Purpose: Woody species use is a short-term indicator of grazing utilization on woody plants, shrubs, and trees along streambanks. Woody vegetation (shrubs and trees) is an important component of many stream-associated riparian areas. Many healthy woody species provide strong, deep root systems that stabilize streambanks, filter sediment, shade streams, and provide habitat diversity. Most riparian woody plants (shrubs and trees) require freshly deposited or disturbed soil to germinate and establish. The most frequent deposition or disturbance is along the streambank. This area, within 3 feet of the greenline, has the highest occurrence of woody species establishment along a stream (Winward 2000). Cattle commonly graze on palatable woody plants occurring on gravel and sandbars and deposits along the floodplain (Kauffman et al. 1983).

Woody-species use may serve as a trigger for moving livestock at a predetermined level of use (e.g., light, moderate, etc.). It may be used to determine the level of browsing during the grazing period. Woody species use may help establish the relationship between the level of grazing use by large herbivores (e.g., cattle, sheep, horses, elk, moose, and deer) and the long-term condition of woody plants along the greenline. This indicator may also be used to help distinguish between livestock and wildlife browsing.

b. Background: The procedure described here was adapted from the landscape appearance method described in *Utilization Studies and Residual Measurements* (USDI, BLM 1996b), which is an ocular estimate of key woody species (e.g., willow, alder, birch, dogwood, aspen, and cottonwood) use. It is based on the amount (percentage) of the current year's leaders on the woody species rooted within a plot 2 m wide (centered on the greenline) and the length of the sample interval. Estimates are based on a range or class of use of the available current year's leaders on a single plant.

The method was adapted for use along streambanks to evaluate livestock and other large herbivore use on those shrubs, that most directly impact the streambanks. Only shrubs with more than 50 percent of the current year's leaders within reach of grazing animals are evaluated.

Other methods were considered, including the twig length measurement and Cole browse methods. These methods were developed for upland shrubs, such as bitterbrush and mahogany, which have limited water availability. None of these methods have been extensively tested on riparian shrubs.

The twig length measurement method was found to be time consuming and to have high observer variability (Hall and Max 1999). The variability was a result of the uncertainty about knowing what and how to measure. This was further complicated by twig growth continuing after grazing on some riparian shrubs and the apparent stimulation of the growth of lateral twigs following grazing. Another compounding factor was the inability to differentiate use by bud-eating birds such as grosbeaks from use by large herbivores (Hall and Max 1999).

The Cole browse method uses incidence of leader (twig) use, i.e., the percent of individual twigs used on an available shrubs. This method appeared to have some of the same problems as the twig length method, particularly the stimulation of the lateral twig growth, continued growth after grazing, and inability to differentiate between different animals using the terminal bud (USDI, BLM 1996b).

c. Assumptions and Limitations: Where they have the potential to occur, woody riparian plants are important for the stability of streambanks; they also provide shade and habitat diversity. Hall and Max (1999) suggest that it is difficult to measure livestock use on riparian woody plants with any reliable degree of accuracy and precision. Since these plants are important, it is assumed that having an estimate of the use is important for determining the success of a grazing management prescription. Detailed rules for describing browsing on woody vegetation help with consistency.

Many stream reaches have low numbers of riparian woody species due to years of heavy use, mechanical and chemical removal, and stream channel alteration activities such as straightening. Low numbers of woody plants result in relatively small sample sizes that produce lower precision and accuracy. Because samples are taken randomly along the streambanks, these low numbers of plants make it difficult to get an adequate sample without sampling the same plants twice.

The average percent use should not be used as a grazing use standard, but rather it should be an indication of the browsing impacts within a use class range. For example, if the woody species use is 38 percent, which is in the upper part of the light category, the amount of use should be described as light to moderate. This provides managers with information necessary to determine if the management prescription is likely making progress toward the objectives or if adjustments to the management prescription should be considered.

d. Relationship to Other Indicators: Woody species use along with woody species age class and greenline composition can be used to help determine the health of the woody plants within 1 m of the greenline. The health of these plants is an important factor contributing to the stability of the streambanks, aquatic habitat, and water quality.

e. Procedure:

Step 1. Establish the Plot Size: Woody species use is observed within a plot 2 m wide (1 m on each side of the greenline) by the length of the interval between quadrats (figure 15). It is helpful to use the measuring rod or handle of the frame to determine if a plant is rooted within the plot.

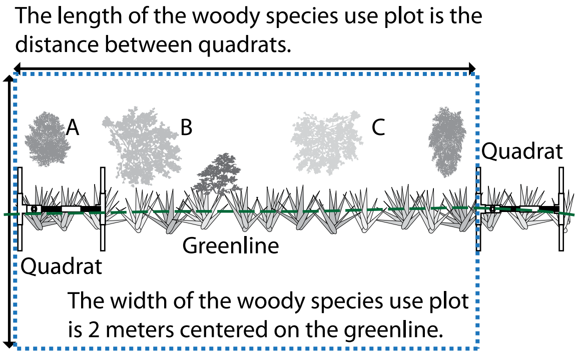


Figure 15. Select the first woody plant (A) within the plot and determine the utilization on that plant. This is repeated for each key woody species (B and C) within the plot. A 2-m measuring rod centered on the greenline is often used to locate plants within the plot. The monitoring frame has a 1-m-long handle, which may also be used to determine if individual woody plants are rooted within the plot.

Table 1. Woody Species Browse Height by Animal Class (USDI, BLM 1992)

Class of Animal	Height Grazed	
	Feet	Meters
Cattle	5.0	1.5
Sheep, antelope, bighorn sheep	3.5	1.1
Horses, elk, and moose	7.0	2.1
Deer	4.5	1.4

Step 2. Determine the Available Current Year's Growth: Available woody species are plants having more than one-half (50 percent) of the current year's leaders within reach of the grazing animal. When the first plant has more than 50 percent of the current year's leaders above the reach of the grazing animal, the shrub is considered unavailable for grazing and the plant is not considered for woody species use. For example, table 1 shows that cattle typically graze to a height of 1.5 m above the ground. The observer(s) would only consider key woody plants that have most of their current year's leaders below 1.5 meters. Woody plants with over 50 percent of the current year's leaders above 5 feet are considered unavailable for cattle.

Step 3. Evaluate the Closest Plant: Observer(s) evaluate the first available key woody plants rooted within the plot for grazing use (see figure 15). If the first plant of a species is not available, go to the next closest plant within the plot. Common key woody species include most species of willow, alder, birch, dogwood, cottonwood, and aspen. If no key woody plants are encountered within the plot, leave the cell in the MIM Field Data Sheet blank.

Step 4. Determine the Woody Species Use Class: Plants are classified into a "use class" (see table 2). These use class descriptions are the standards by which use is judged. This process is repeated for each key woody species within the plot. Review grazing class descriptions periodically while reading the plots to maintain precision and accuracy. Record by species the midpoint (see table 2) for the appropriate use class.

f. Timing:

1) Isolating Livestock Use: Woody species use may be measured just before and just after livestock enter the grazing unit. This helps to determine how much use was from livestock and if there was grazing use on woody species by other large herbivores.

Table 2. Woody Species Use Classes and Descriptions
(adapted from the landscape appearance method, USDI, BLM 1996b)

Class	Midpoint	Description
Unavailable	Blank	Shrubs and trees that have most (over 50%) of their actively growing stems over 1.5 m (5 feet) tall for cattle grazing. This should be adjusted if the questions to be answered involve other herbivores (see table 1).
Slight (0%-20%)	10	Browse plants appear to have little or no use. Available leaders may show some use, but 20% or less of the current year's leaders have use.
Light (21%-40%)	30	There is obvious evidence of use of the current year's leaders. The available leaders appear cropped or browsed in patches and 60%–79% of the available current year's leaders of browse plants remain intact.
Moderate (41%-60%)	50	Browse plants appear rather uniformly used and 40%–59% of the available current year's leaders remain intact.
Heavy (61%-80%)	70	The use of the browse gives the general appearance of complete search by grazing animals. Most available leaders are used and some terminal buds remain on browse plants. Between 20% and 39% of the available current year's leaders remain intact.
Severe (81%-100%)	90	The use of the browse gives the appearance of complete search by grazing animals. There is grazing use on second and third years' leader growth. Plants show a clublike appearance, indicating that most active leaders have been removed. Only between 0% and 19% of the current year's leaders remain intact.

2) ***Trigger Monitoring:*** Measuring may be done during the grazing season to determine if grazing use on woody species has reached a predetermined amount, which would trigger moving livestock from the grazing area. Such measuring may also provide an early warning of impending damage to the plants.

3) ***End of Season:*** Use may be measured after the livestock grazing season to determine the amount of use on woody species.

g. Metrics: The following metrics are used to summarize woody species use data:

- ***Average Use by Woody Species:*** This metric is calculated as the arithmetic average of woody species use values recorded for each plot, based upon the use category or class for each species. As stated previously, this metric value should be reported in terms of the use class; i.e., if the average of all plots for *Salix boothii* is 38 percent, the use class is "light to moderate" (see Data Analysis Module – "Graphs" worksheet).

- ***Average Use for All Woody Species:*** This metric is calculated using the same equation as for average use by individual woody species, but it is the weighted average for all woody species at the site (see Data Analysis Module – "Data Summary" worksheet).

4. Greenline Composition:

a. Purpose: Riparian vegetation is critically important for the stability of streambanks, streambank morphology (width, depth, and shape), water quality, and aquatic habitat quality (Hansen et al. 1988). Livestock grazing, as well as other anthropogenic disturbances, may impact vegetation through reduced vigor, soil compaction, changing species, and physical disturbance of the streambanks (Platts 1991; Wyman et al. 2006). Sampling along the greenline is designed to account for the continuous line of vegetation occurring along most streambanks (Winward 2000). Since streams are dynamic, measuring vegetation along the greenline, which can move in response to annual streamflow levels, is particularly effective for understanding the overall condition and health of the stream reach. Determining the species of plants along the streambanks provides an indication of the condition, based on the health and amount of deep, strong-rooted vegetation, and the trend toward or away from the objectives established for the stream reach.

The greenline can also be composed partially or entirely of embedded rock and/or anchored wood, which influences stream function and habitat quality. Because of this, both embedded rock and anchored wood are also recorded.

b. Background: The concept of greenline composition was developed to provide a way to observe and measure the vegetation that is most critical to maintaining stream channel stability (Winward 2000). Winward describes a method using a continuous measurement and stratifies vegetation by riparian community type. Previously, a dominant and subdominant procedure was used for recording the relative proportion of plants within the plot (limiting subdominant plants to those with a minimum of 25 percent cover in the plot). The procedure was changed to record the relative vegetation composition for each herbaceous species having 10 percent or more foliar cover to improve efficiency. Use of the markings on the monitoring frame makes it possible to rapidly estimate the foliar cover of the species. Data recorded by percent cover rather than dominance provides a more accurate species composition.

c. Assumptions and Limitations: The greenline follows the streambank as erosion and deposition occur along a stream. Therefore, the composition of vegetation in this zone directly affects the condition of streambanks and overall stream condition. The major plant species along the greenline are helpful for analyzing the effects of livestock grazing along a stream.

The procedure described here is not intended to identify all plant species along the greenline. It is intended to show those plants that are in a large enough proportion to directly affect streambanks. This procedure may be modified to identify all species. However, such a procedure would be much more time consuming and require a high degree of plant identification skills.

This procedure is not intended to provide data concerning vegetation on the floodplain or other associated riparian areas. When there are management questions concerning these areas, use other procedures such as vegetation cross-section composition (Winward 2000), riparian cross-section vegetation (PIBO-EM 2008), and ecological type identification and ecological status determination (Weixelman et al. 1997).

d. Relationship to Other Indicators: Greenline composition is closely related to streambank stability, woody species age class, and greenline-to-greenline width. Streambanks dominated by deep-rooted riparian vegetation result in stable streambanks, narrow channel widths, shading, habitat diversity, and terrestrial insect production.

e. Procedure:

Step 1. Develop a Species List: Prior to collecting vegetation data on the greenline, it is critical for observers to identify the plant species located on the site. Complete a reconnaissance of the site to identify and make a list of all vascular plant species that may occur along the greenline before sampling the plants.

Step 2. Record Herbaceous Vascular Plants (Perennial): Viewing from directly above the plot at 90 degrees to the ground surface, record by species the relative amount of foliar cover for herbaceous plants rooted in the plot having 10 percent or more foliar cover by composition. The monitoring frame is marked to provide references for 10-, 25-, and 50-percent areal extent (see figure 16).

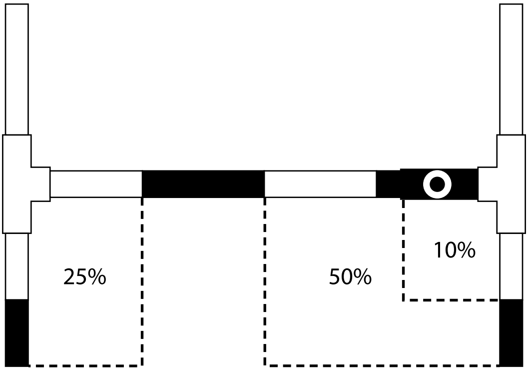


Figure 16. The frame is marked with modified Daubenmire quadrat markings. These markings provide a visual estimate of the proportions of the quadrat.

For example, if a plot contains 25 percent foliar cover of Nebraska sedge and 25 percent cover of Kentucky bluegrass with 50 percent bare ground, the observer would record compositions of 50 percent Nebraska sedge and 50 percent Kentucky bluegrass. Embedded rock and anchored wood compositions would also reflect their relative contributions to cover. For example, if a plot contained 25 percent foliar cover of Nebraska sedge, 25 percent cover of Kentucky bluegrass, 25 percent bare ground, and 25 percent embedded rock, the relative compositions would be 33 percent Nebraska sedge, 33 percent Kentucky bluegrass, and 33 percent embedded rock. Nothing is recorded for bare ground, litter, or nonvascular plants.

The total for all understory combinations (herbaceous plants, and/or embedded rock and/or wood, and/or woody plant seedlings) must not exceed 100 percent.

Step 3. Record Woody Species Understory: Seedling woody plants, as defined in tables 10 and 11 in the "Woody Species Age Class" section, are not considered overstory and are recorded as percent foliar cover by composition along with the understory herbaceous vegetation.

Step 4. Record Woody Species Overstory: Overstory includes all young and/or mature woody plant species, as defined in tables 10 and 11 in the "Woody Species Age Class" section, either rooted in or overhanging the plot. Woody plants overhanging the plot must be rooted on the side of the stream being sampled. Do not record plants that are rooted on the opposite bank.

Foliar cover is not used for woody species overstory composition. If any part of a woody plant occurs in the overstory directly above the plot, it is counted as part of the composition. The observer does not attempt to estimate its relative cover but records 100 percent if there is one species in the overstory, 50 percent for each if there are two species in the overstory, 33 percent for each if there are three species in the overstory, and so forth.

Step 5. Record Embedded Rock and Anchored Wood: Rock that is at least 15 cm in diameter and at least partially embedded in the streambank with no evidence of erosion behind it, talus slopes, and bedrock and/or logs or root wads that are anchored into the streambank and large enough such that high flows are not likely to move them are considered. Record the percentage of the total of understory vegetation, rock, and/or wood.

Step 6. Record Grouped Plants: To the extent possible, all plants with 10 percent or more foliar cover should be identified by species. When individual plant species are less than 10 percent, but together comprise at least 10 percent of the foliar cover, they may be combined into groups, such as mesic forbs (MFE for early seral and MFL for late seral) or mesic graminoids (MG), dry shrubs (DS) or dry grass (DG), sedge (CAREXRH for rhizomatous and CAREXTF for tufted), and rush (JUNCUS).

Step 7. Record Important Plants with Less Than 10 Percent Foliar Cover: Do not record any plant species with less than 10 percent foliar cover in the data entry form. Any important plants, such as noxious weeds or rare plants, may be recorded in the comments sheet by plot number.

Step 8. Record No Greenline Cover: When no greenline cover exists (i.e., vegetation, embedded rock, or wood) within 6 m of the water's edge, record "NG." The Data Analysis Module uses values of bare ground, early ecological status, and a greenline streambank stability rating of "0."

f. Timing: Samples should be collected when plants are identifiable. Timing may vary according to climate and intensity of grazing use. The greenline should not be flooded at the time of sampling.

g. Metrics: The following metrics are used to summarize greenline composition data:

- ***Greenline Composition by Species (Percent):*** This metric represents the relative proportions of individual species to the whole vegetative composition. It is calculated by summing the percent composition for each species over all plots divided by the number of plots in which the particular species was encountered times 100. The composition is presented by vegetation type (forb, graminoid, shrub, tree, other). This metric is presented in the "Graphs" worksheet of the Data Analysis Module (see Data Analysis Module – "Graphs" worksheet).

- ***Greenline Ecological Status Rating:*** This is a measure of the average ecological status rating of plants as defined by Winward (2000). Plants are weighted according to their percent composition. This metric is calculated using plant successional status ratings and Winward's riparian capability groups (table 3). It is further adjusted where a woody overstory component should be present but currently is not present (see Data Analysis Module – "Data Summary" worksheet).

- ***Site Wetland Rating:*** This metric represents the average wetland rating of plants as computed using the site wetland rating (Coles-Ritchie 2005) (table 4). Wetland indicator status (USDI Fish and Wildlife Service 1993) values for individual species may vary by region. The Data Analysis Module accounts for that variation (see Data Analysis Module – "Data Summary" worksheet).

- ***Hydric Plants Percent:*** This is a measure of the proportion of the composition consisting of hydric plants. It is calculated by summing the total percent composition of plants rated as "hydric" divided by the total percent composition of all plants. "Hydric" is defined as those plants classified in the wetland indicator status (USDI Fish and Wildlife Service 1993) as facultative wetland to obligate (see Data Analysis Module – "Data Summary" worksheet).

- ***Modified Winward Greenline Stability Rating:*** This metric represents the average stability rating of plants as defined in the plant list in the Data Analysis Module. Winward (2000) greenline stability ratings (table 5) are derived from categories as explained previously (see Data Analysis Module – "Data Summary" worksheet).

- ***Percent Woody Composition:*** This is a measure of the percentage of plots containing woody plants. It is calculated by summing the number of plots with woody plants divided by all plots in the survey (see Data Analysis Module – "Data Summary" worksheet).

Table 3. Greenline Ecological Status (Winward 2000)

Value	Rating
0-15	Very Early
16-40	Early
41-60	Mid
61-85	Late
86+	Potential Natural Community (PNC)

Table 4. Site Wetland Rating (Coles-Ritchie 2005)

Value	Rating	Value	Rating
0	UPL	58	FAC+
8	UPL+	67	FACW-
17	FACU-	75	FACW
25	FACU	83	FACW+
33	FACU+	92	OBL-
42	FAC-	100	OBL
50	FAC		

Table 5. Modified Greenline Stability Rating (Winward 2000)

Value	Rating
<4	Low
5-6	Moderate
>6	High

- ***Hydric Herbaceous Percent:*** This metric represents the percentage of plots containing hydric (facultative wetland to obligate) herbaceous plants. It is calculated by summing the number of plots in which a hydric herbaceous species was encountered and dividing by all plots in the survey (see Data Analysis Module – "Data Summary" worksheet).

- ***Vegetation Biomass Index:*** This metric represents an index that is proportional to the estimated total biomass of vegetation along the greenline (table 6). It is calculated by averaging the heights of woody plants, weighted by species composition, adding this to the average stubble height of herbaceous plants, also weighted by species composition, and multiplying the sum by the average percent cover along the streambanks (Saunders and Fausch 2007) (see Data Analysis Module – "Data Summary" worksheet).

Table 6. Vegetation Biomass Index

Index	Relative Value
<10	Very Low
10 - 20	Low
20 - 30	Moderate
30 - 40	High
>40	Very High

- ***Percent Forbs:*** This is a measure of the percent of all plants in the sample identified as "forbs" in the plants list in Data Analysis Module. This metric is calculated by dividing the total composition of forbs by the total composition of all plants in the survey (see Data Analysis Module – "Data Summary" worksheet).

- ***Plant Diversity Index:*** The plant diversity index is calculated by multiplying the number of plant species by average species composition on the plots and dividing by the standard deviation of plant species composition (table 7). This metric is calculated using the macro in the "Graphs" spreadsheet of the Data Analysis Module

Table 7. Plant Diversity Index

Index	Relative Value
<1	Very Low
1 – 2	Low
3 – 4	Moderate
5 – 6	High
>6	Very High

5. Woody Species Height Class:

a. Purpose: This indicator estimates the heights of woody plants adjacent to the stream. Because heights are estimated by observation, height classes were developed to facilitate a reasonable level of observer agreement. Heights are indicators of stream shading and woody biomass production. Woody species height is useful in monitoring trends in woody plant structure adjacent to the stream.

b. Background: The temperature of a stream is an important factor that determines the types, abundance, and distribution of aquatic organisms that live in a stream (Gordon et al. 2004). Water temperature in streams (particularly small streams less than 10 m wide) is directly affected by the amount of shading along the stream (Allan and Castillo 2007). Woody species adjacent to the stream are most effective for providing shade and thermal insulation to the water (Gordon et al. 2004). Temperature is a common water quality issue for cold water biota in many states.

Woody species along the edge of the stream provide a large amount of biomass. Woody species along with herbaceous vegetation influence terrestrial insect production. Recent research has demonstrated that terrestrial insect production associated with streamside vegetation is a major component of the diets for salmonid fishes and can be influenced by livestock grazing effects on that vegetation (Saunders and Fausch 2007).

The procedure for measuring woody species height is described in PIBO-EM (2008) and is based upon the protocol documented in Bonham (1989). It is an easy and efficient method of describing the structure of woody vegetation along the edge of the stream channel.

c. Assumptions and Limitations: Many woody species encountered along the streambanks are shrubs and small trees that are less than 8 m tall. These plants may include species such as willow, alder, birch, snowberry, and rose. This procedure allows for describing the overstory layers of woody vegetation along the streambanks by identifying the height class by species.

The tallest height class used in this procedure is all woody vegetation greater than 8 m. Thus, trees more than 8 m tall, such as aspen, cottonwood, conifers, and alder, are estimated by a broad range greater than 8 m. If there are layers of vegetation over 8 m tall, their relative position in the layer will not be recognized.

When actual heights of woody species would answer specific questions, the procedure must be modified to measure the actual heights of the woody plants. This modification increases the amount of time needed to collect the data. The Data Analysis Module would also need to be modified to recognize the measured height, rather than the height class. The Data Analysis Module estimates average woody species height by applying the average height class to a regression equation that predicts actual height in meters.

d. Relationship to Other Indicators: Woody species height class provides additional information describing the condition of greenline vegetation. It provides information concerning the growth of woody species over time.

Woody species height class provides useful input to vegetation height in the optional shading variable of the stream segment temperature (SSTEMP) model widely used to predict stream temperature (Bartholow 2002). Shading is one factor that contributes to stream temperature regulation. GGW may also correlate to the stream width.

e. Procedure: Record the height class of each woody species plant with cover over the plot using the ranges from PIBO-EM (2008) as shown in table 8. Record the tallest height class (inside or outside the plot) of an individual with at least some cover over the plot. For example, if a willow has one branch hanging over the plot at 1 m above the ground, yet when looking at the entire plant, it is 3 m high at its tallest point, record class 4 (2.01 to 4 m). When multiple layers of woody plants occur over the plot, record the height class for each woody species listed in the greenline composition.

Table 8. Woody Species Height Class (PIBO-EM 2008)

Height Class	Height Range
1	0.0 – 0.5 m
2	> 0.5 – 1.0 m
3	> 1.0 – 2.0 m
4	> 2.0 – 4.0 m
5	> 4.0 – 8.0 m
6	> 8.0 m

f. Timing: Woody species height should be measured at the same time as the greenline composition.

g. Metrics: The following metrics are used to summarize woody species height class data:

- ***Percentile Height:*** Percentiles from the frequency distribution are summarized showing the height of woody plants at various frequencies of occurrence. For example, the 50 percentile is that height for which 50 percent of the plants are shorter (see Data Analysis Module – "Graphs" worksheet).

- ***Shade Index:*** This metric represents the average height of all woody plants divided by the average GGW. Shade increases with increasing plant height and decreasing

GGW (Bartholow 2002) (table 9) (see Data Analysis Module – "Data Summary" worksheet).

Table 9. Shade Index

Value	Shading
<0.5	Very Low
0.5 – <1.0	Low
1.0 – <2.0	Moderate
2.0 – <4.0	High
≥4.0	Very High

- ***Average Woody Plant Height:*** The average woody plant height class is applied to a regression equation to compute predicted woody plant height. In the "Data Summary" worksheet in the Data Analysis Module, the average for all woody species heights is presented. In the "Graphs" worksheet, the average height is displayed for each woody species. The regression equation was developed using the log of species height versus age class and has an R squared of 0.99. The equation is:

  H =10^(-0.7083129+0.297*Average Height Class)

  (See Data Analysis Module – "Data Summary" worksheet.)

6. Streambank Stability and Cover:

a. Purpose: Streambanks are the steep-sloped sides of the stream channel and are most susceptible to erosion during high flow events. Stability along the edge of the first bench or bankfull elevation down to the stream's scour line is the area within the channel that is most vulnerable to erosion by water because streamflow up to the bankfull level occurs almost every year (Leopold 1994). Bankfull discharge performs most of the geomorphic work in most river systems (Wolman and Miller 1960). Streambank stability is strongly influenced by streamside vegetation (Bauer and Burton 1993). The loss or modification of deep-rooted bank vegetation is problematic for stability.

Streambanks can become unstable or unable to resist the erosive effects of high streamflows as a result of improper livestock grazing. Bare streambanks, either in erosional or depositional positions of the stream, are considered unstable due to their vulnerability to erosion. The effect of excessive grazing is to alter the streamside vegetation composition resulting in a dominance of plants that are more vulnerable to erosion (Platts 1991; Bauer and Burton 1993). Mass wasting may also result from breakoffs, hoof slide, and hoof shear related to the physical disturbances of trampling (Bauer and Burton 1993; Powell et al. 2000). Unstable streambanks can lead to accelerated bank erosion and subsequent channel widening, increased sediment supply, decreased sediment transport capability, and damaged fisheries habitat.

At each plot location, features that describe streambank stability are recorded. Those features are used in the Data Analysis Module to compute percent streambank stability and cover. Plots are a subsample of the length of the streambank; therefore, streambank stability using this procedure estimates the proportion of streambank that is stable and that is covered.

b. Background: This procedure is based upon an earlier version described by Bauer and Burton (1993) and later by Overton et al. (1997). Modifications were later made by the PACFISH/INFISH Biological Opinion Effectiveness Monitoring (PIBO-EM) Team to minimize subjectivity (Kershner et al. 2004). The current version further reduces subjectivity by allowing observers to record features that define the condition rather than to record the stability class. Rules are used to increase measurement precision.

c. Assumptions and Limitations: Streambank stability can be used to monitor livestock grazing and, potentially, other disturbance effects only if the procedures are adhered to strictly and the definitions are understood and followed. Streambank stability must be assessed by well-trained observers.

Because of how the observations are made, streambank stability can only be assessed when the stream is flowing below the scour line, usually well after the seasonal peak flow event. Streambank stability monitoring is voided by assessments made when the banks are flooded.

Archer et al. (2004) found that only 18 samples were needed to detect a change of 5 percent (Type I error of 0.1), and from tests on 12 different streams, the authors determined an average of 54 samples were needed to detect a change of 10 percent. However, site variability may have significant influence on the sample size needed. Tests conducted by the authors indicated sample size estimates as low as 5 and as high as 102 to estimate streambank stability within 10 percent of the mean. Use of an electronic sample size estimator built into the Data Entry Module will help ensure an adequate number of samples was collected before leaving the field site.

In tests of repeatability for streambank stability, using an earlier version of the method, Archer et al. (2004) found the maximum deviation between crews was only 18 percent corresponding to a coefficient of variation of 4.6 percent. On average, crews agreed 82.7 percent of the time. This compares with the author’s testing from 43 replicates, which resulted in an average difference between observers of 8.2 percent (stability) and 8.5 percent (cover), with coefficients of variation of 9 percent (stability) and 8 percent (cover). More details can be found in appendix F.

d. Relationship to Other Indicators: Streambank alteration and GGW are affected by streambank stability. In addition, the Winward greenline stability rating, an estimator of the vegetative contribution to bank stability, is related.

e. Procedure:

Step 1. Determine Streambank Location: Streambanks are defined as that part of the channel between the scour line and the edge of the first relatively flat bench above the scour line. The figures in appendix E provide examples of streambank locations.

Step 2. Observe Factors Influencing Stability on the Streambanks Associated with the Frame: The plot (area observed for streambank stability) extends parallel to the stream a distance of one frame length (50 cm) and perpendicular to the stream between the scour line and the lip of the first bench. Typical scour line indicators are the elevation of the ceiling of undercut banks at or slightly above the summer low-flow elevation or, on depositional banks, the lower limit of sod-forming or perennial vegetation. The lip of the first bench is at the point on the bench where the slope changes from the relatively flat top to the slope toward the stream.

Step 3. Answer the Following Questions: Each of the following questions is answered with a letter abbreviation (such as "D" for depositional). One set of questions is answered for the streambank associated with each plot location and the answers are entered into columns F, G, and H of the "DMA" worksheet in the Data Entry Module or on the MIM Field Data Sheet (appendix B, part 2).

1) What kind of streambank is it? The choices are "**D**epositional" or "**E**rosional":

- **Depositional (D):** This applies to all streambanks associated with sand, silt, clay, or gravel deposited by the stream. These are recognizable as "bars" in the channel margins adjacent to the greenline and at or above the scour line. Stream bars are typically lenticular-shaped mounds of deposition on the bed of the stream channel adjacent to or on the streambank. Depositional streambanks are usually at a low angle from the water surface and are not associated with a bench.

- **Erosional (E):** This applies to all banks that are not "Depositional." Erosional streambanks are normally at a steep angle to the water surface and are usually associated with a bench and/or terrace. Such banks typically occur on the outside of meander bends and on both sides of the stream in straight reaches. When there is sufficient stream energy, they may also occur on the inside bank of a meander bend.

2) **Is the streambank covered?** The choices are "**C**overed" or "**U**ncovered":

- **Covered (C):** This applies to banks with at least 50 percent foliar cover of perennial vegetation (including roots); at least 50 percent cover of rocks 15 cm or larger; at least 50 percent cover of anchored large woody debris (LWD) with a diameter of 10 cm or greater; or a combination of the vegetation, rock, and/or LWD covering at least 50 percent of the bank area (50 cm wide from the scour line to the first bench).

- **Uncovered (U):** This applies to all banks that are not "Covered."

3) **Is the streambank stable?** This applies to erosional banks only. For depositional banks, leave this cell blank. The Data Entry and Analysis Modules allow only one code in each cell, so the observer records "**F**racture," "**Sl**ump," "**Sl**ough," "**E**roding," or "**A**bsent" for the single most prominent feature:

- **Fracture (F):** This applies to the top of the bank where a visible crack is observed. The fracture has not separated into two separate components or blocks of a bank. Cracks indicate a high risk of breakdown. **The fracture feature must be at least one-fourth of a frame length.**

- **Slump (S):** This applies to a streambank that has obviously slipped down resulting in a separate block of soil/sod separated from the bank. **The slump feature must be obvious and at least one-fourth of a frame length.**

- **Slough or "Sluff" (SL):** This applies to banks where soil or sod material has been shed or cast off and has fallen from and accumulated near the base of the bank. "Slough" typically occurs on banks that are steep and bare. **The slough must be obvious and at least one-fourth of a frame length.** Slumps and sloughs may be created by excessive animal trampling (see appendix E, figures E8 and E9).

- **Eroding (E):** This applies to banks that are bare and steep (within 10 degrees of vertical), usually located on the outside curves of meander bends in the stream. Undercut banks are scoured or eroded below the elevation of the base of sod or the roots of vegetation, and because such erosion occurs mostly below the scour line, it is not considered "eroding" bank. Such undercut banks are stable as long as there is no slough, slump, fracture, and/or erosion above the scour line or ceiling of the undercut bank. **The erosion feature must be obvious and at least one-fourth of a frame length.**

- **Absent (A):** This applies when none of the above listed characteristics are present.

f. Timing: Streambank stability is measured in conjunction with streambank alteration to quantify the levels of streambank alteration that do not constrain streambank stability condition or recovery. In establishing allowable levels of streambank alteration, streambank stability should be measured in conjunction with streambank alteration annually, both before and after grazing. If a reference is available, measurements both before and after grazing would be made in the ungrazed reference area to isolate natural effects. In the absence of the need to quantify streambank alteration criteria, streambank stability should be measured approximately once every 3 years to evaluate changes over time. An ungrazed reference should be used to assess trends related to livestock grazing.

g. Metrics: The following metrics are used to summarize streambank stability and cover data:

- ***Streambank Stability:*** The number of plots classified as "stable" are divided by the total number of plots and expressed as a percent (see Data Analysis Module – "Data Summary" worksheet).

- ***Streambank Cover:*** The number of plots recorded as "covered" are divided by the total number of plots and expressed as a percent (see Data Analysis Module – "Data Summary" worksheet).

7. Woody Species Age Class:

a. Purpose: Woody species age class data help determine if woody plants are establishing along the streambank. Winward (2000) found that use of the greenline edge as the center of the measurement helps to ensure that sampling is done in a setting where regeneration of woody riparian species is most likely to occur.

b. Background: Winward (2000) concluded that understanding the age class, structure, and density of woody species along the stream margins provides information necessary to evaluate the results of management. Woody species regeneration, as described by Winward (2000), consists of a 6-foot wide belt adjacent to and on each side of the greenline and on both sides of the stream. All woody species (excluding rhizomatous woody species) were counted and placed in an age class defined in the procedure described in Winward (2000). The procedure for the MIM protocol was modified by using a 0.42 by 2 m plot (two lengths of the 42- by 50-cm monitoring frame placed perpendicular to and with 1 m on each side of the greenline) instead of a continuous belt, which increases precision and allows evaluating the data using statistical methods. Single- and multiple-stem species are grouped by age class and the number of plants is recorded for each class.

c. **Assumptions and Limitations:** Stream disturbance or sediment deposition is often required for germination and establishment of many woody species along streams (Winward 2000). The most frequent sediment deposition is along the margins of streams resulting from relatively frequent small floods, those with return frequencies of every 2 or 3 years. This deposition creates a relatively frequent return of conditions conducive for woody species to germinate and establish.

The procedure described here is designed to provide decisionmakers with information concerning the recruitment of woody species along streams. For systems with the potential to produce woody vegetation, this procedure helps provide an understanding of whether the woody species are increasing, decreasing, or maintaining numbers and age classes.

d. **Relationship to Other Indicators:** Woody species age class is only a part of the data needed to understand condition and trend. It should be used in conjunction with greenline composition, streambank stability and cover, and GGW. Woody species use provides information to assess whether browsing is a factor contributing to a change in the population and health of the woody vegetation along the greenline.

e. **Procedure:**

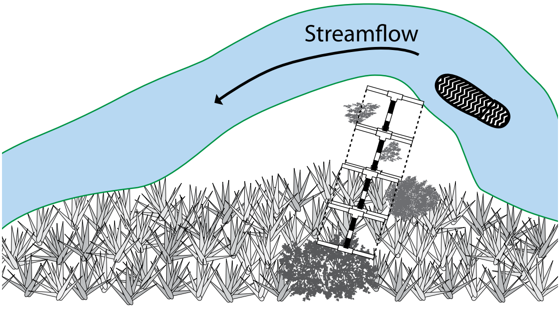


Figure 17. The monitoring frame placement. The monitoring frame is placed perpendicular to the greenline.

Step 1. Determine Plot Placement: The woody species plot is 0.42 m wide by 2 m long (1 m on each side of the greenline), with the frame placed perpendicular to the greenline as shown in figure 17. Place the frame end-to-end on each side of the greenline so that the entire 2 m are sampled.

Step 2. Distinguish Individual Plants: It is sometimes difficult to distinguish individual plants from one another when shrubs have multiple stems close together. In such cases, consider all stems within 0.3 m of each other at ground level as the same plant and record the age class of the entire shrub to which that stem is connected, even if part of the shrub is outside of the plot. The presence of even one stem within the frame requires the observer to determine if that stem is connected to others outside of the frame.

Step 3. Determine Age Class: Place the end of the monitoring frame on and perpendicular to the greenline, and determine the age class (see tables 10 and 11) of each woody plant by species **rooted** within the monitoring frame. Record the number of all woody plants by species according to their age class. Do not count woody species overstory not rooted within the frame.

Table 10. Woody Species Age Class for Single-Stemmed Species [e.g., cottonwood or aspen (*Populus* spp.)]

Age Class	Single Stem Species
Seedling	Stem is <1 m tall or <2.5 cm in diameter at 50% of height from ground level.
Young	Stem is >1 m tall and 2.5 cm to 7.6 cm in diameter at 50% of height from ground level.
Mature	Stem is > 1 m tall and >7.6 cm in diameter at 50% of height from ground level.

Table 11. Multistemmed (Clumpy) Woody Species Age Class (e.g., most willows, alder, and birch)

Age class	Stems and Height
Seedling	1 stem <0.5 cm in diameter at the base and <0.5 m tall.
Young	2 to 10 stems less than 1 m tall or 1 stem >0.5 cm in diameter at the base and less than 1 m tall
Mature	>10 stems over 1 m tall

Step 4. Record Woody Root Sprouting and Rhizomatous Species: It is difficult to age class rhizomatous and root sprouting species such as coyote willow (*S. exigua*), wild rose (*Rosa* spp.), snowberry (*Symphoricarpos* spp.), cottonwood root sprouting (*Populus* spp.) and golden currant (*Ribes aureum*), etc.; therefore, if root sprouting and rhizomatous species occur in the plot, record a 1 in the rhizomatous column.

Step 5. Record Low-Growing Shrubs: Some low-growing shrubs are considered mature when they are less than 0.5 m tall. etc. When a question arises, use the plant growth form descriptions in the literature to determine the appropriate age class.

f. Timing: Sampling should be conducted when woody plants can be identified and at the same time as greenline composition and woody species height class is done.

g. Metrics: The following metrics are used to summarize woody species age class data:

- ***Percent Seedlings (By Species):*** This metric represents the proportion of woody plants encountered on all plots that are classified as "seedlings." It is calculated by summing all seedlings encountered and then dividing the sum by the total number of woody plants encountered in the survey (see Data Analysis Module – "Data Summary" worksheet).

- ***Percent Young (By Species):*** This metric is the same as the percent seedling metric except that it is calculated only for those plants classified as "young" (see Data Analysis Module – "Data Summary" worksheet).

- ***Percent Mature (By Species):*** This metric is the same as the percent seedling except that it is calculated only for those plants classified as "mature" (see Data Analysis Module – "Data Summary" worksheet).

- ***Percent Rhizomatous Woody:*** This is a measure of the proportion of woody plants classified as "rhizomatous." It is obtained from the total of all plots in which rhizomatous woody plants were encountered divided by the total number of plots in which any woody plant was encountered (see Data Analysis Module – "Data Summary" worksheet).

8. Greenline-to-Greenline Width (GGW):

a. Purpose: Greenline-to-greenline width (GGW) is the nonvegetated distance between the greenlines on each side of the stream. It provides an indication of the width of the channel, reflecting disturbance of the streambanks and vegetation. As stream channel margins are disturbed by trampling or excessive vegetation consumption, streams may erode the streambanks, causing a lateral erosion of the streambank and streamside vegetation. This results in a shifting out, or widening of the distance between greenlines within the nonvegetated channel. The GGW measurement may also reflect the bankfull width. As stated by Winward (2000):

> Most often the greenline is located at or near the bankfull stage. As flows recede and the vegetation continues to develop summer growth, it may be located part way out on a gravel or sandbar. At times when banks are freshly eroding or, especially when a stream has become entrenched, the greenline may be located several feet above bankfull stage.

The loss of vegetative integrity and breakdown of streambanks by livestock trampling may lead to bank erosion and subsequent channel widening (Rosgen 1996). Because vegetation is frequently related to bank stability, the nonvegetated width between greenlines is an excellent way to monitor this effect on the channel. As channels widen, water depth decreases with potential negative effects on aquatic habitat and water temperature.

b. Background: Many stream channels become overwidened as a result of vegetative changes and physical disturbance to streambanks from improper livestock grazing (i.e., streambank trampling and shearing) or other physical disturbances to the streambanks. Improper livestock grazing can alter stream habitats by channel widening and/or incision (Clary et al. 1996; Clary 1999; Clary and Kinney 2002; Kauffman and Krueger 1984). Under improper grazing, protective vegetation is weakened or removed, and trampling may induce a sloping streambank profile (Clary and Kinney 2002). Subsequent erosion of weakened streambanks during floods results in a wider, shallower stream channel profile. These changes to stream channels can be detrimental to biota (Bohn 1986). Observations at research sites indicated stream width reductions in overgrazed streams with improved grazing management of riparian zones. The average amount of narrowing was inversely associated with the level of grazing intensity. Between 1990 and 1994, width changes (measured as a proportion of the original measurement) were: a 41 percent reduction in areas with no grazing, a 34 percent reduction in areas with light grazing, and an 18 percent reduction in areas with medium grazing. Stream depth, on the other hand, was variable through time and appeared to change primarily in response to climatic events. After a flood event in 1996, channel depth at the ungrazed site increased to 2.33 times the original depth. This vertical scour likely resulted from the longer term effect of channel narrowing (Clary 1999).

Commonly, the width of stream channels is determined by measuring channel width at the bankfull level. Detailed measurements of width and depth are accomplished by surveying channel cross-section profiles. This method, at a large number of positions along the stream, is impractical because it requires identification of bankfull indicators, which in disturbed streams are often missing. Testing by the authors indicates that too few width measurements do not adequately estimate mean greenline-to-greenline width dimension due to site variability (see details of testing in appendix F).

As summarized by Bauer and Ralph (2001), the major concern with use of width measurements at bankfull level is the reliability of the method. Bankfull width is determined by using field characteristics such as sediment surfaces and profile breaks to identify the elevation of the active floodplain surface. These definitions are vague, and the actual selection of bankfull level is, at best, subjective.

Other field methods have measured the "wetted width" of the stream. Although this level in the channel is easily identifiable, unfortunately, wetted width varies dramatically by streamflow. Because it is normally measured during low or intermediate streamflows, it provides little information about the overall channel characteristics of the measured stream.

To achieve an adequate sample for estimating the mean GGW, take measurements at each plot location. The results are a mean width of the nonvegetated stream channel. As streambanks recover, the stream channel typically narrows and the average GGW is reduced.

c. Assumptions and Limitations: GGW is the average nonvegetated distance between the greenline on each side of the stream. It provides an indicator of the stream channel width. As disturbed and usually overwidened streams recover, the channel will narrow. Hence, narrowing GGWs are indicators of stream recovery. Objectives specific to GGW should be developed from reference sites when such information is available.

Results of the authors' testing (54 tests) indicated reasonably good repeatability. The coefficient of variation averaged 8 percent, which according to the literature, indicates good agreement among observers (see appendix F). The average difference between observers was less than 0.5 m. The number of samples needed to predict the mean, within 10 percent, at 90 percent confidence, averaged 67. As with other indicators, the adequate sample sizes varied among test streams, from a low of 21 to a high of 109.

The measurement of GGW assumes the use of some kind of measuring instrument (measuring rod, tape, laser rangefinder) with an instrument accuracy of less than 0.5 m (0.1 m preferred).

d. Relationship to Other Indicators: The GGW reflects the vegetative composition and stability of the streambanks. As vegetation shifts from deep-rooted hydric types to more shallow-rooted mesic and xeric types, streambanks become vulnerable to erosion and lateral migration, allowing the GGW to expand. Likewise, as streams recover from past disturbance, a greater abundance of deep-rooted riparian-wetland vegetation may become established on the streambanks, resisting stream erosion and building more stable streambanks. As banks become stabilized, vegetation may encroach on the channel, particularly on bars in the margins of the stream, allowing the GGW to narrow. Data from measuring GGW should be used with greenline composition and streambank stability and cover to evaluate these effects.

One way to evaluate the precision in locating the greenline is to consider the repeatability of GGW measurements. The average difference among observers is 0.43 m. Since observers must use the same procedures to locate the greenline, presumably differences among observers are influenced, and probably largely determined by, the bias in its location. Thus it is encouraging that observers are reasonably in agreement with GGWs.

e. Procedure:

Step 1. Measure the Distance between the Greenlines on Each Side of the Stream and Perpendicular to the Waterflow at Each Plot Location: Using a laser rangefinder is the most expedient way of measuring the distance but may be difficult in woody vegetation. A rangefinder reduces the time required to do the measurements by about two-thirds. Other less expensive options include using measuring rods and tape measures.

Measure from the greenline associated with the center bar on the monitoring frame (near the toe of the boot) (see appendix A, figure A1) to the greenline on the opposite side of the stream. The measurement is taken at each plot location on both sides of the stream. Measure the width to the nearest 0.1 meter.

Step 2. Subtract Vegetated Island Measurements: When a vegetated island (with at least 25 percent foliar cover) is encountered along the line, determine the total distance between the greenlines and deduct the length of the vegetated portion of the island to determine the nonvegetated GGW (see appendix G, figures G1, G3, and G5).

Nonvegetated islands are included in the GGW measurement even if they consist of embedded rock or anchored wood (see appendix G, figure G5, line A).

NOTE: Do not measure GGW when no greenline (NG) is recorded. Leave the MIM Field Data Sheet (or electronic data entry) blank.

f. Timing: Measurements should be made during the low streamflow period after annual vegetative encroachment has ended. This will usually occur after streamflow has drawn down sufficiently to allow drying of streambanks. Streams that are confined by the actively flowing channel at low flow, such as those controlled by base or spring flows, will have very little vegetative encroachment. Streams that have considerable historic disturbance or flashy flows or are steep in the declining limb of the hydrograph may experience a great deal of vegetative encroachment soon after high water. This indicator helps document stream channel recovery over time. Since the recovery process may be relatively slow, it is recommended that the procedure be repeated every 3 to 5 years. The procedure is relatively easy and only requires about 1 hour per DMA.

g. Metrics: The following metric is used to summarize GGW data:

- ***GGW:*** This metric is the average of GGW measurements at a site in meters. The metric is based on measured data that usually fits a normal probability distribution (see Data Analysis Module – “Data Summary” worksheet).

9. Substrate:

a. Purpose: Bed material sampling is used to detect impacts of channel disturbance and the effects of management prescriptions and mitigations on the substrate over time. Channel instability often leads to channel widening, where the energy balance between erosion and deposition shifts toward deposition and therefore fining of the substrate (Powell et al. 2000). Such increases in fines may degrade aquatic habitat by restricting the living spaces of substrate-dwelling organisms and by limiting the oxygen transfer to incubating eggs (Powell et al. 2000).

b. Background: There is a sizeable amount of literature that supports the contention that excess substrate fines are adverse to salmonids (Bauer and Ralph 2001; McHugh and Budy 2005; Platts 1991). Bunte and Abt (2001) provide an excellent literature summary with guidelines for substrate assessment. They also found that pebble counts are an efficient and effective method for measuring surface substrate size distribution and percent fines. In applications to a national forest, Potyondy and Hardy (1994) found pebble counts to be reasonably simple, rapid, and useful in determining the effects of land management activities and land disturbances on instream fine sediment. They concluded that pebble counts can only detect change when relatively high magnitude impacts (low precision) are evaluated. They used just 100 particles to estimate substrate-size distribution. Testing by the authors of the MIM protocol suggested higher precision can usually be obtained with more than 100 particles. To characterize the substrate, pebble counts sample a preset number of particles (at least 200) along transects across the channel. The cross-channel transects are evenly spaced along the length of the DMA.

c. Assumptions and Limitations: This procedure applies primarily to wadable, gravel- and cobble-bed streams. Such streams have mean particle sizes ranging from 2 to 256 mm in diameter (Bunte and Abt 2001). Because of the wide range of bed material sizes, and because of the complex interactions of particles during erosion, transport, and deposition, the substrate may become spatially heterogeneous and difficult to sample.

To adequately sample gravel- and cobble-bed streams, reaches of at least 5-7 channel widths in length should be included (Bunte and Abt 2001). Sampling the entire length of the DMA (20 channel widths) is recommended to ensure spatial variability is accounted for in the sample scheme. If not, variability through time may reflect spatial heterogeneity more than actual adjustments in substrate size distributions.

Because the purpose is to sample particle-size distribution related to channel instability, the surface of the streambed is the focus of this procedure. Sampling the subsurface strata (e.g., particles at depth) is more intensive and beyond the purpose and scope of this monitoring procedure.

It may be challenging to collect surface particles in some situations. In addition, care must be taken to avoid sampling algae, which may appear in the form of fine particulates covering the surfaces of rocks in the substrate. Algae are not part of the substrate and should not be counted as part of the fines. Individual fine particles located between larger particles may be difficult to pick from the substrate, others may be heavily embedded into the substrate and hard to dislodge, still others may be too heavy to pick up. As noted by Bunte and Abt (2001), using different methods to sample substrate at the same location may yield different results. Thus trend over time should be based upon the same technique applied to each sampling event.

The guidelines on bed material sampling provided by Bunte and Abt (2001) include an excellent summary of the literature and the principal base reference for this protocol.

With respect to repeatability, the statement by Bunte and Abt (2001) is especially appropriate for substrate sampling:

> Operator training is extremely important. When selecting particles from a predefined streambed location, or even when measuring particle sizes in a preselected sample of rocks, there is less variability between the results of experienced operators than between those obtained by novices. Field personnel need to be trained to perform procedures accurately, to avoid bias, and to use equipment that reduces operator induced error.

Observers should take caution when sampling cross sections associated with fast water (>1.5 m/sec). Fine particles can become easily washed away when collecting from the substrate, causing inaccuracies. In a DMA containing a cascade, for example, if the plot cross-section occurs at the cascade, the observer should be careful to avoid losing particles in fast water. Likewise, sampling in locally deep water is problematic for the observer because the substrate is beyond arm's length. However, as suggested by Bunte and Abt (2001), sampling in deep water can be mitigated by visually estimating particle size classes or by collecting substrate with a long-handled scoop or "reach extender." Diving with a wet or dry suit may also be used in situations with abundant deep water.

As summarized by Bunte and Abt (2001), sources of error in pebble counts may result from observer variability. The most common error is to favor larger sized particles when sampling substrates with fines lodged between larger particles. Rather than collect the fines, the observer selects the larger particle, often out of convenience. The systematic procedure described here helps to reduce this error by requiring the observer to collect the sample directly beneath the tape or rod at the given point of measurement. Still, the use of the index finger to touch the substrate and then select what is touched as the sample may miss small interspaces and the associated fines between particles using either procedure. For this reason, percent fines and the lower percentile particles (D_{16} and D_{30}) may be underestimated.

One way to reduce bias associated with bed sampling, particularly in fast mountain streams with a lot of cobble-sized particles, is to use the sampling frame designed by Bunte and Abt (2001). This frame is placed on the bed of the stream at the designated points along the tape or rod within the cross section. It contains a grid intersection that defines exactly where the particle is located. The observer then attempts to extract that particle, or if very small and subject to being washed away, records its size class visually. In this way, if the point of measurement occurs exactly on the interspace between two cobbles, the material within that interspace is collected for the sample. The frame is metal so as to easily submerge and rest on the substrate and it is 60-cm square. Elastic bands are stretched across the frame in two directions to form the grid intersection. Multiple elastic bands can be used to make multiple grid intersections.

Despite known bias towards larger particles and away from fines, note that there was better observer agreement (repeatability) at the authors' test sites on percent fines (coefficient of variation or CV = 6 percent) than on median particle size (CV = 29 percent). This agreement is likely because median particle sizes are calculated from size classes (slots in the template) that represent broader ranges as particles increase in size, and fines are measured in small slots that are closer to the actual size of the particle. Additionally, most of the test sites were located on low-gradient streams where the frequency of encountering larger particles that mask fines in their interspaces is low. Typically sand and gravel with dispersed cobbles dominated these sites and allowed for less bias in collecting the smaller particles from the substrate.

With respect to accuracy, as summarized in Bunte and Abt (2001), a 100-count particle-size sample is usually too low to compare particle-size distributions over time. The authors' testing indicated that adequate sample sizes range between 74 and 384 (with an average of 229) to estimate the mean within 10 percent at 90 percent confidence (see appendix F). The range of sample sizes varied according to heterogeneity of the substrates at the test sites. Small sample sizes of 74 were indicated at a site with relatively homogeneous substrate, and large sample sizes were indicated at a heterogeneous or highly variable site.

d. Relationship to Other Indicators: Substrate size distributions and fine sediment abundance are related to channel stability indicated by streambank stability and cover, greenline composition, GGW, and streambank alteration. Streamside vegetation consumption and bank trampling by livestock can lead to streambank destabilization, which may lead to increased bank erosion, subsequent channel widening, decreased water velocity, and increased deposition.

e. Procedure: Beginning with the second plot in the survey, samples are collected at every other plot location (or 20 total transects), evenly spaced along the entire length of the DMA. Transects are located at even numbered plots, from plot 2 to plot 40, in the upstream direction of the survey only. Collect and measure the diameter of 10 pebbles at each transect. Samples should be collected within the active channel only. Never sample a particle above the scour line. Depositional features (e.g., point bars) that are not covered by vegetation and located below the scour line are considered streambed material and should be included in the sample.

Step 1. Determine the Interval Length to Obtain 10 Particles in the Cross Section: Use a measuring rod or tape stretched across the stream at the plot location. Divide the width of the active channel by 10 (the active channel is located between the scour lines of the stream). Alternatively, if a measuring rod or tape is not used, count the number of heel-to-toe steps across the active channel width, divide by 10, and collect samples at each division. For very small streams, collect five samples on each of two crossings (i.e., cross once, move upstream 0.5 m, then cross again).

Step 2. Determine the First Sample Location and Begin Sampling Particles: Start the cross channel transect at one-half the interval length, and then collect all subsequent particles at the full interval length. For example, if the width of the active channel at the sample location is 5 m, the sample interval is 0.5 m and the first sample is collected at 0.25 m from the scour line. All subsequent samples are collected at 0.5-m intervals, and the last sample, or particle number 10, should be approximately 0.25 m from the scour line on the opposite side of the channel.

The observer locates the sample interval, places the index finger at that point, and without looking at the streambed, reaches into the stream and obtains the first particle in the substrate that touches the index finger. Sample the entire streambed width at each transect. If pacing, measure to the starting point (i.e., 0.25 m as above) with the rod, collect the first sample there, and then pace at approximately 0.5-m intervals from that location to the other sample points across the channel.

Step 3. Measure the Diameter of Samples Collected: Place the particle in the smallest slot in the template through which it will pass, or if a template is not used, measure the middle width (intermediate or "B" axis) of the particle in millimeters. Visualize the B axis as the smallest width of a square hole that the particle could pass through. A template is an excellent tool for measuring particle sizes and is highly recommended to reduce subjectivity in selecting and measuring the B axis.

If a small particle falls into the fines category, is touched in between larger particles, and the observer is unable to collect it, the particle size can be estimated (i.e., <6 mm).

The Stream Systems Technology Center (1996) provides a complete description of the template. The instrument can be purchased from commercial sources for approximately $50.00 each.

Sampling with templates (gravelometers) provides for higher accuracy of measurements than with rulers because of reduced bias or observer error (Bunte and Abt 2001). In addition, measuring particle sizes with a template makes sampling quick and more efficient. Openings in the template match the Wentworth scale and can be used to estimate the particle-size class or *phi* based on Krumbein and Sloss (1963).

Spacing between particles must be greater than the largest particle within the cross section to avoid double sampling of the same particle, which may bias the sample or cause serial correlation towards larger particles. If it is not possible to obtain 10 particles in one pass, move upstream 0.5 m (or at least a distance to avoid the same boulders), and use the sampling interval estimated as the channel width divided by the remaining number of particles. More than two passes may be required for some small streams.

f. Timing: Substrate is easier to sample when less water is in the stream. The summer low-water season is preferred over periods of bankfull or near-bankfull flows. To evaluate trends over time, sampling every 3 to 5 years should be applied as a minimum. Sampling should also be done after large flow events, when substrates undergo the greatest changes.

g. Metrics: The following metrics are used to summarize substrate data:

- ***Percentiles:*** The computation of the cumulative-frequency distribution is of use with particle-size analyses (Bunte and Abt 2001). The result is a plot of the percentage cumulative-frequency distribution, showing the percent fines by size class. Percentile values can then be used to describe size classes for which x percent is finer. The Data Analysis Module uses the D_{16} (16 percent), D_{50} (50 percent), and D_{84} (84 percent) percentiles. The percentile is calculated as follows (Bunte and Abt 2001):

$$\mathbf{D_X = (A_2 - A_1) \cdot (B_X - B_1/B_2 - B_1) + A_1}$$

Where: D_x is the diameter of the particle at the desired cumulative-frequency level x,

B_1 and B_2 are the cumulative percent frequency just below and above the desired cumulative percent frequency x, and

A_1 and A_2 are the particle sizes that correspond to the cumulative frequencies B_1 and B_2.

(See Data Analysis Module – "Substr" worksheet.)

- ***Percent Fines:*** In addition to the particle-size percentiles, the Data Analysis Module calculates the percent of particles finer than 6 mm. It computes the percentage of particles that passed or fit through the smaller slots (the 2-, 2.8-, 4-, and 5.6-mm slots) in the template as a proportion of the total sample (see Data Analysis Module – "Data Summary" worksheet).

- ***D16, D50, and D84 Particle Sizes:*** The particle size that is representative of all particles for which 84, 50, or 16 percent of the particles are smaller is presented in diameter (mm) and the value on the phi scale (Krumbein and Sloss 1963). The phi scale is a log transformation of the particle sizes and is calculated by taking the negative log (base 2) of the median particle diameter. This metric is particularly useful in assessing particle-size statistics since the Wentworth scale is nonlinear (see Data Analysis Module – "Data Summary" worksheet).

10. Residual Pool Depth and Pool Frequency:

a. Purpose: Two procedures, water width and maximum (thalweg) depth, have been removed from the protocol described in Burton et al. (2008) as testing results and reviews by experts found such measures, as designed, are of questionable value for monitoring trend through time. Both water width and thalweg depth are streamflow dependent; therefore, changes may largely reflect stage differences rather than management effects. Channel width should be monitored by measuring cross sections at the bankfull elevation. This measurement may require a survey of the hydraulic geometry of the channel, particularly where bankfull width indicators are lacking. Field techniques for surveying the bankfull channel cross section and width are contained in Harrelson et al. (1994). Because these techniques require surveying equipment and a substantial amount of field time, they are beyond the scope of the MIM protocol.

A more appropriate approach to monitoring the maximum (thalweg) depth or structure of the channel is to measure the "thalweg profile" to estimate residual pool depth as described by Lisle (1987), with field techniques also summarized in Harrelson et al. (1994). This technique measures water depth along the deepest part of the channel and calculates the difference in depth between riffle crests (or pool tails) and pool bottoms (or maximum depth of pools). That difference is the residual pool depth. Residual pool depths can be measured independent of stream discharge, which is important in detecting trends.

b. Background: Because pools are vital to the rearing and production of fishes, pool depth has been an important component of stream habitat measurements. For example, Mossop and Bradford (2006) found a positive correlation between mean maximum residual pool depth and the density of Chinook salmon in 16 tributary reaches to the Yukon River in Canada. As described previously, livestock grazing can result in the breakdown of streambanks and the loss of stabilizing vegetation. These impacts can lead to secondary effects within the channel itself. In a review of the literature, Powell et al. (2000) concluded that channel characteristics, including channel width and depth, as well as bed material were often reported to be affected by livestock grazing in riparian areas.

c. Assumptions and Limitations: Field testing found poor repeatability among observers when pool structure within the channel is complex. Such conditions appear to be common in cobble- and boulder-dominated substrates. In those instances, there is scouring that often results in the development of small pocket pools that can be missed by some observers. The procedure discussed here appears to work well in gravel, gravel/cobble, sand, silt, and clay bottom streams. Also, very small streams, or those that are intermittent in streamflow, may not develop good pool structure. Observers are cautioned about the use of this indicator in such conditions.

d. Relationship to Other Indicators: Residual pool depth is related to streambank stability and cover as well as GGW and particle-size distribution. As summarized by Powell et al. (2000), as the channel margins become less stable, greenline-to-greenline or channel width will usually increase. Such an increase will usually be associated with a decrease in channel depth. This reduced channel depth is often caused by a decrease in the ability of the stream to scour the bed and may also be associated with a higher sediment load in the channel.

e. Procedure: Pools are defined as any depression in the bed of the stream resulting in relatively low water velocity and often as relatively flat water surfaces when measured at low streamflows (usually mid- to late summer). Such streamflows should be well below the bankfull stage.

Distances are measured using a rod, tape measure, or laser rangefinder and depths are measured using a measuring rod.

Step 1. Identify the Riffle Crest: Starting at the downstream marker of the DMA, proceed upstream and identify the first riffle crest (pool tail). The riffle crest is best identified when viewed from downstream and is the upstream end of shallow, rippling water where it exits or spills from a pool. To be classified as a pool it must be at least as wide as one-half the wetted width of the stream (small pocket pools are not counted). The distance from the lower marker in the DMA to the first riffle crest is not measured. An effective technique is to have one individual wade in advance of the observer to sense the maximum or thalweg depths of the channel.

Step 2. Determine the Thalweg Depth of the Riffle Crest: The observer measures and records the thalweg depth. The depth measurement is made in the thalweg or deepest part of the channel in the stream cross section.

Step 3. Measure the Distance from the Riffle Crest to Pool Bottom and the Pool Bottom Depth: Proceed upstream into the pool bottom (the deepest point in the pool) and record the distance from the riffle crest to the pool bottom. The pool should occupy at least one-half of the stream width. The depth of the pool at the deepest point is also measured and recorded. Continue measuring and recording both the distance between riffle crests and pool bottoms and the depth of each at the thalweg until reaching the top of the DMA. When a riffle crest is within the DMA and the pool bottom is beyond the upstream DMA marker, measure and record the riffle crest depth, the distance to the pool bottom and the pool bottom depth of the pool upstream of the upper marker.

f. Timing: The residual pool depth and pool frequency indicators help document stream channel recovery over time. Because the recovery process may be relatively slow, it is recommended that the procedure be repeated every 3 to 5 years. The procedure is relatively easy and requires about one-half hour per DMA.

g. Metrics: The following metrics are used to summarize residual pool depth and frequency data:

- ***Pool Frequency:*** This is a count of all pools encountered divided by the thalweg length of the DMA. This metric is the relative frequency or number of pools per mile (see Data Analysis Module – "Data Summary" worksheet).

- ***Mean Residual Pool Depth:*** Residual depth is calculated as the average of all differences between riffle crest depth and pool maximum depth in the survey (see Data Analysis Module – "Data Summary" worksheet).

V. USE THE DATA ENTRY AND ANALYSIS MODULES AND THE MIM DATABASE

A. Introduction

A Data Entry Module has been developed for use with personal digital assistants (PDAs) or digital field data recorders using a Microsoft Office Excel spreadsheet format. The file can be downloaded into Excel on a personal computer (PC) and then converted to Pocket Excel or Excel Mobile with the PDA through synchronization or by using a data card, thumb drive, or Bluetooth. Instructions are included in the module. Calculations and analyses are limited in this module to avoid delays caused by the much-reduced processing speed of handheld computers.

The Data Analysis Module is designed to calculate metrics and summarize raw data for interpretation. Data are entered directly or collected from the Data Entry Module using a routine that automatically opens the file, copies the entered data, and pastes it into the Data Analysis Module. The Data Analysis Module will also format the data for export to a Microsoft Access database. Alternatively, it is possible to record data on paper forms and then enter the data directly to the Data Analysis Module rather than the Data Entry Module, which is used for electronic field entry only. Detailed instructions are contained within the Data Analysis Module.

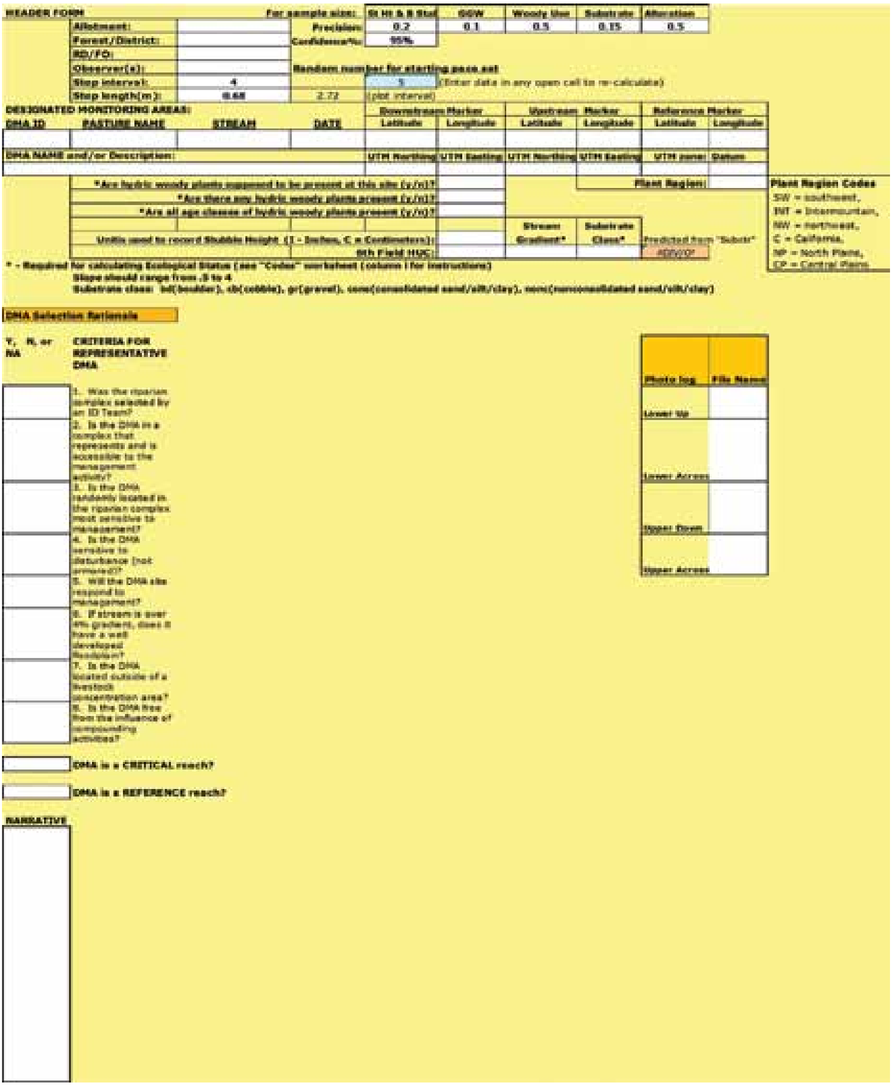
B. Data Entry Module

This module is used exclusively for entering data electronically from the field. Any hand-held computer that supports Microsoft Excel (e.g., Excel Mobile) can be used to enter the data. The module must first be uploaded from a PC. Many hand-held computers come with a universal serial bus (USB) or serial port that can be connected by cable to the PC. They also come with Microsoft ActiveSync software that allows synchronization for copying files between devices. If the field unit has Bluetooth capability, it can communicate with Bluetooth-enabled devices without cables. Files can usually be transferred between units by enabling Bluetooth on both units and making the devices discoverable to each other. Another method of file transfer is to use CompactFlash (CF) and/or Secure Digital Input/Output (SDIO) cards if the devices have these slots. Check the computer's user guide for methods of connectivity and file transfer.

The Data Entry Module contains nine worksheets, which are usually accessible on the hand-held computer from a drop-down menu. On the PC they are displayed at the bottom of the screen as shown in figure 18.

Figure 18. The worksheets in the Data Entry Module.

The “Instructions” tab leads to information describing the contents and use of each worksheet. Data are entered into the “Header,” “DMA,” “Substr,” “Thal,” and “Comments” worksheets. An example of a “Header” worksheet is shown in figure 19.



HEADER FORM

Allotment:
Forest/District:
RD/FO:
Observer(s):
Step interval: 4
Step length(m): 0.68

For sample size:	St Ht & B Stu	GGW	Woody Use	Substrate	Alteration
Precision:	0.2	0.1	0.5	0.15	0.5
Confidence%:	95%				

Random number for starting pace set
1 (Enter data in any open cell to re-calculate)
2.72 (plot interval)

DESIGNATED MONITORING AREAS:

DMA ID	PASTURE NAME	STREAM	DATE	Downstream Marker Latitude	Downstream Marker Longitude	Upstream Marker Latitude	Upstream Marker Longitude	Reference Marker Latitude	Reference Marker Longitude

DMA NAME and/or Description:

UTM Northing	UTM Easting	UTM Northing	UTM Easting	UTM zone:	Datum

*Are hydric woody plants supposed to be present at this site (y/n)?
*Are there any hydric woody plants present (y/n)?
*Are all age classes of hydric woody plants present (y/n)?
Units used to record Stubble Height (I = Inches, C = Centimeters):
6th Field HUC:

Plant Region:

Stream Gradient*
Substrate Class*
Predicted from "Substr"
#DIV/0!

Plant Region Codes
SW = southwest,
INT = Intermountain,
NW = northwest,
C = California,
NP = North Plains,
CP = Central Plains

* - Required for calculating Ecological Status (see "Codes" worksheet (column I for instructions)
Slope should range from .5 to 4
Substrate class: bd(boulder), cb(cobble), gr(gravel), cons(consolidated sand/silt/clay), ncns(nonconsolidated sand/silt/clay)

DMA Selection Rationale

Y, N, or NA	CRITERIA FOR REPRESENTATIVE DMA
	1. Was the riparian complex selected by an ID Team?
	2. Is the DMA in a complex that represents and is accessible to the management activity?
	3. Is the DMA randomly located in the riparian complex most sensitive to management?
	4. Is the DMA sensitive to disturbance (not armored)?
	5. Will the DMA site respond to management?
	6. If stream is over 4% gradient, does it have a well developed floodplain?
	7. Is the DMA located outside of a livestock concentration area?
	8. Is the DMA free from the influence of compounding activities?

DMA is a CRITICAL reach?

DMA is a REFERENCE reach?

NARRATIVE

Photo log	File Name
Lower Up	
Lower Across	
Upper Down	
Upper Across	

Figure 19. A “Header” worksheet from the Data Entry Module.

An important component of the "Header" worksheet is the DMA selection rationale. This is where the interdisciplinary team documents their DMA selection process. The type of DMA is indicated and a narrative describes the location of the DMA.

The "Codes" worksheet contains code and class definitions for various indicators in the system. The "Plant Lists" worksheet contains a description of the common and scientific names and codes for common riparian plants. The "Stats" worksheet contains a description of the statistics used to estimate sample size for some of the indicators.

C. Data Analysis Module

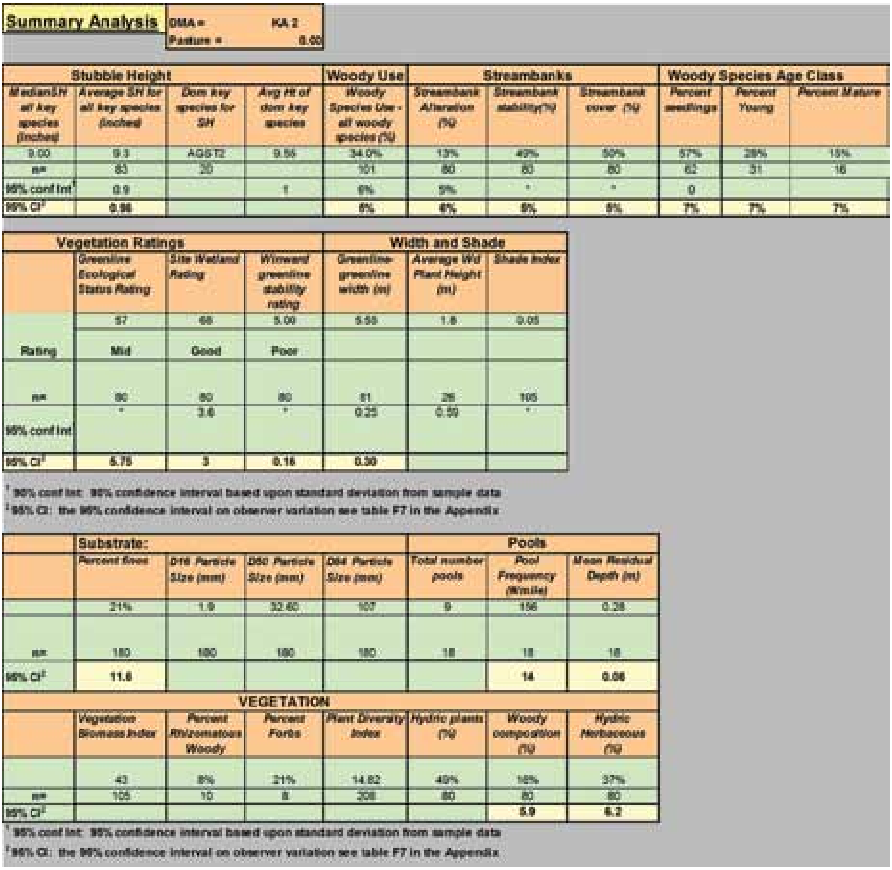
The Data Analysis Module calculates 32 basic metrics in the "Data Summary" worksheet, plus 8 additional metrics for individual plant species and woody plant heights in the "Graphs" worksheet. The basic metrics are described in previous sections for each indicator.

The Data Analysis Module is organized much like the Data Entry Module and contains worksheets as shown in figure 20.

Figure 20. The worksheets in the Data Analysis Module.

The main difference between this module and the Data Entry Module is the addition of the "Data Summary," "Export," "Calcs," and "Graphs" worksheets. The 32 basic metrics are displayed in the "Data Summary" worksheet (figure 21). This worksheet also contains a proper functioning condition (PFC) validation worksheet that displays many of the metrics relative to PFC checklist items (Prichard et al. 1998). The "Graphs" worksheet (figure 22) contains more detailed metric summaries for plant species, including a graph of relative species composition. The "Export" worksheet contains two rows of data displaying metric summary data used in the MIM Access database and in the appropriate table structure for ease of transfer to the database. The "Calcs" worksheet describes how each metric is mathematically derived.

Several of these metrics contain condition descriptors such as "good," "low," or "medium." Tables for these are contained in the "Calcs" worksheet.



Summary Analysis

DMA = KA 2

Pasture = 0.00

Stubble Height				Woody Use	Streambanks			Woody Species Age Class		
MedianSH all key species (inches)	Average SH for all key species (inches)	Dom key species for SH	Avg Ht of dom key species	Woody Species Use - all woody species (%)	Streambank Alteration (%)	Streambank stability(%)	Streambank cover (%)	Percent seedlings	Percent Young	Percent Mature
9.00	9.3	AGST2	9.55	34.0%	13%	49%	50%	57%	28%	15%
n=	83	20		101	80	80	80	62	31	16
95% conf Int[1]	0.9		1	6%	5%	*	*	9		
95% CI[2]	0.96			6%	6%	6%	6%	7%	7%	7%

Vegetation Ratings				Width and Shade		
	Greenline Ecological Status Rating	Site Wetland Rating	Winward greenline stability rating	Greenline-greenline width (m)	Average Wd Plant Height (m)	Shade Index
	57	68	5.00	5.55	1.8	0.05
Rating	Mid	Good	Poor			
n=	80	80	80	81	26	105
95% conf Int[1]	*	3.6	*	0.25	0.59	*
95% CI[2]	5.75	3	0.16	0.30		

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

	Substrate:				Pools		
	Percent fines	D16 Particle Size (mm)	D50 Particle Size (mm)	D84 Particle Size (mm)	Total number pools	Pool Frequency (#/mile)	Mean Residual Depth (m)
	21%	1.9	32.60	107	9	156	0.28
n=	180	180	180	180	18	18	18
95% CI[2]	11.6					14	0.08
VEGETATION							
	Vegetation Biomass Index	Percent Rhizomatous Woody	Percent Forbs	Plant Diversity Index	Hydric plants (%)	Woody composition (%)	Hydric Herbaceous (%)
	43	8%	21%	14.82	49%	16%	37%
n=	105	10	8	208	80	80	80
95% CI[2]						5.9	6.2

[1] 95% conf Int: 95% confidence interval based upon standard deviation from sample data

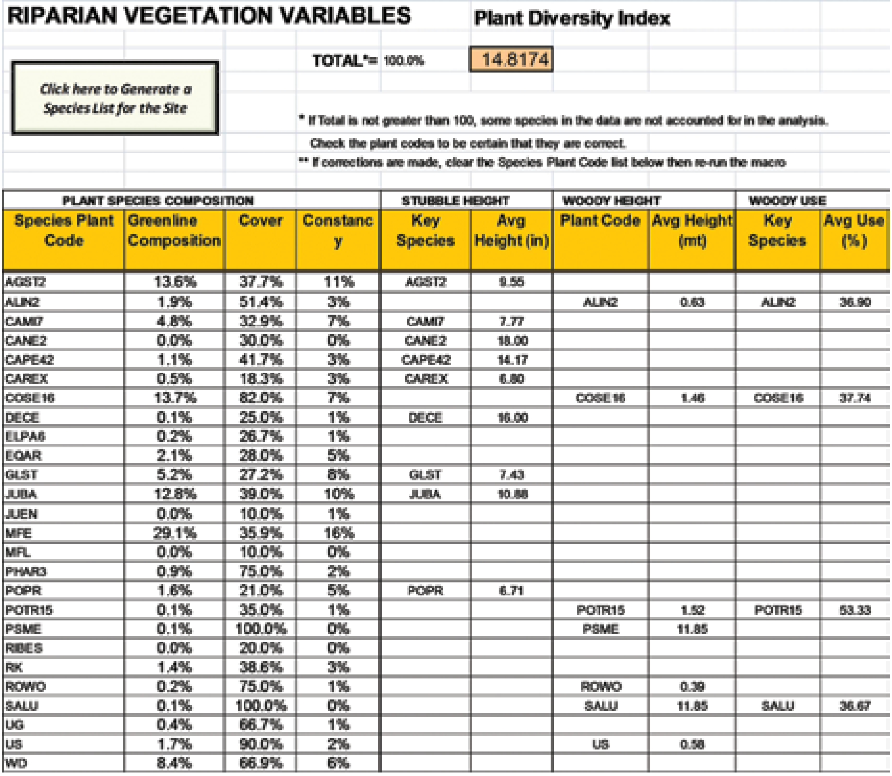
[2] 95% CI: the 95% confidence interval on observer variation see table F7 in the Appendix

Figure 21. An example of a "Data Summary" worksheet.

D. PFC Validation

The MIM protocol can be used to validate proper functioning condition (PFC) assessments for lotic riparian-wetland areas (Prichard et al. 1998). The PFC method assesses a much broader reach of stream; however, it is a qualitative method for assessing the condition of riparian-wetland areas and is not designed to be a long-term monitoring tool. The PFC assessment uses hydrology, vegetation, and erosion/deposition (soils) attributes and processes to qualitatively assess the condition of riparian-wetland areas. Many of these same attributes can be quantitatively measured using the MIM protocol. Procedures for the PFC assessment are found in Prichard et al. (1998).

Use the Data Analysis Module to address or validate PFC checklist items and final ratings. The "Data Summary" worksheet in that module presents quantitative values for several of the checklist items in the PFC assessment. The PFC assessment user guide states that



RIPARIAN VEGETATION VARIABLES

Plant Diversity Index

TOTAL*= 100.0% 14.8174

* If Total is not greater than 100, some species in the data are not accounted for in the analysis.
Check the plant codes to be certain that they are correct.
** If corrections are made, clear the Species Plant Code list below then re-run the macro

PLANT SPECIES COMPOSITION				STUBBLE HEIGHT		WOODY HEIGHT		WOODY USE	
Species Plant Code	Greenline Composition	Cover	Constancy	Key Species	Avg Height (in)	Plant Code	Avg Height (mt)	Key Species	Avg Use (%)
AGST2	13.6%	37.7%	11%	AGST2	9.55				
ALIN2	1.9%	51.4%	3%			ALIN2	0.63	ALIN2	36.90
CAMI7	4.8%	32.9%	7%	CAMI7	7.77				
CANE2	0.0%	30.0%	0%	CANE2	18.00				
CAPE42	1.1%	41.7%	3%	CAPE42	14.17				
CAREX	0.5%	18.3%	3%	CAREX	6.80				
COSE16	13.7%	82.0%	7%			COSE16	1.46	COSE16	37.74
DECE	0.1%	25.0%	1%	DECE	16.00				
ELPA6	0.2%	26.7%	1%						
EQAR	2.1%	28.0%	5%						
GLST	5.2%	27.2%	8%	GLST	7.43				
JUBA	12.8%	39.0%	10%	JUBA	10.88				
JUEN	0.0%	10.0%	1%						
MFE	29.1%	35.9%	16%						
MFL	0.0%	10.0%	0%						
PHAR3	0.9%	75.0%	2%						
POPR	1.6%	21.0%	5%	POPR	6.71				
POTR15	0.1%	35.0%	1%			POTR15	1.52	POTR15	53.33
PSME	0.1%	100.0%	0%			PSME	11.85		
RIBES	0.0%	20.0%	0%						
RK	1.4%	38.6%	3%						
ROWO	0.2%	75.0%	1%			ROWO	0.39		
SALU	0.1%	100.0%	0%			SALU	11.85	SALU	36.67
UG	0.4%	66.7%	1%						
US	1.7%	90.0%	2%			US	0.58		
WD	8.4%	66.9%	6%						

Figure 22. An example table in the "Graphs" worksheet. Frequency-distribution graphs are also displayed here.

"there will be times when items from the checklist need to be quantified" and that "these quantitative techniques are encouraged in conjunction with the PFC assessment for individual calibration, where answers are uncertain, or where experience is limited" (Prichard et al. 1998). The PFC validation table in the Data Analysis Module provides a list of indicators and their quantitative values for the applicable checklist item(s), along with a note describing the indicator's relevance to the item.

E. MIM Database

A geodatabase has been developed for the storage of local MIM data. This database is designed for individual units and does not represent a national agencywide database. A national geodatabase will be developed by the BLM to accommodate MIM data. The local database includes the metrics derived from the "Summary" worksheet of the Data Analysis Module and the header information, including geographic coordinates for the monitoring site. This database can be used to summarize the monitoring data over geographic regions through time. It can be used to store data over time and to facilitate condition and trend

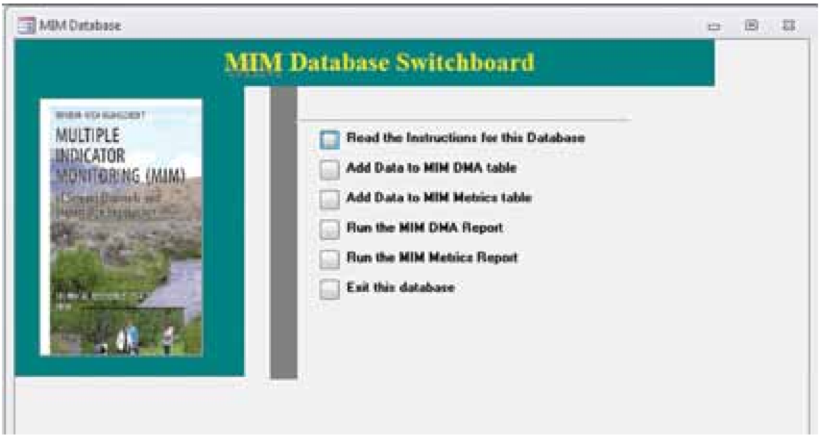


Figure 23. MIM database switchboard showing the components of the system, including the DMA and metrics tables.

analyses and prepare reports. Figure 23 contains a screenshot that generally describes the database and its components.

The switchboard on the top of the database provides an easy way to access the two MIM data tables. Once open, data from the "Export" worksheet in the Data Analysis Module can then be added to the tables. The instructions that accompany the database explain how to transfer summary data from the Data Analysis Module to the database. Two reports are available: one that summarizes DMA descriptions, including rationale for selecting the DMA for each site in the database, and another that presents all metric data for every DMA in the system. Access allows users to easily query and sort data and to display it in geographic information systems. To obtain a copy of this Access database, contact the riparian resource specialist at BLM's National Operations Center.

VI. ANALYZE, INTERPRET, AND EVALUATE MONITORING DATA

A. Introduction

Effective monitoring programs address management objectives. These objectives are driven by key questions related to determining whether or not progress is being made towards meeting the specific, predetermined management objectives. The best way to evaluate whether progress is being made towards achieving the management objectives is to have a monitoring program that detects change through time. To do that, a reasonable level of accuracy and precision in the measurement procedures must be applied.

Field time per site varies from 2 to 4 hours depending upon the indicators chosen for monitoring. If the Data Entry Module is used in the field, data transfer to the Data Analysis Module with subsequent calculation of metrics can be accomplished in less than 1 hour. If data collected in the field is recorded on paper, approximately 2 hours are required to input the data and to verify copy accuracy (for a total of 4 to 6 hours per site).

This protocol was tested in the field using a variety of approaches to evaluate its precision and accuracy. Test results are presented in appendix F.

1. Precision: Precision denotes agreement between repeat observations taken at the same time (within the low-flow season) and at the same place to estimate observer variation. There may be broad-scale yearly variations, such as those associated with climatic variances (Larsen et al. 2004), but within-season variations are expected to be minor in the same year because the indicators are not influenced by streamflow at low flow or the late summer to fall season when the protocol should be applied. If an unusual streamflow event should occur within the low-flow season, the data should be interpreted according to such influences. In this case, a reference reach (reaches) would be useful for calibrating the influence of the unusual event. Potential errors associated with relocating the DMA reach (Larsen et al. 2004) would be minimized as long as the reach is properly monumented.

Observations may be repeated by the same or different individuals. Differences between samples arise from the bias of individual observers. If bias in sampling occurs, results may be inaccurate (Elzinga et al. 1998). Precision is important for interpreting compliance and trend. If, for example, the stubble height grazing use criterion is 4 inches and the precision of the measurement is 0.96 inches, an observation of 3.6 inches would not imply that the criterion has been exceeded. With respect to trend, if the objective for streambank stability is to achieve 80 percent stability and the precision is 8 percent, an 85 percent observation does not mean that the objective has been met. A discussion of test results on MIM indicators, including estimates of precision, is contained in appendix F.

Another form of precision is the sample size. Larger sample sizes come closer to the true mean value for the indicator. A good statistic for this form of precision is the confidence interval, calculated from the sample mean and standard deviation. The sample size needed to achieve desired levels of precision can be predicted by using the standard normal distribution and from field data where the mean and standard deviation are known. The equation is described in appendix F.

Electronic data entry may be used to assess sample size levels while collecting field data. The MIM protocol uses a Microsoft Excel workbook, the Data Entry Module, designed for use with PDAs, which allows computation of the sample sizes needed to predict the mean for various levels of confidence and precision (appendix F).

2. Ability to Detect Change at a DMA: The ability to detect change is critical to effective monitoring results. In stream and riparian systems, change is a relatively frequent natural process. The ability to isolate changes due to management requires that the method be reasonably precise. One statistic that has commonly been used to evaluate precision is the coefficient of variation (CV), but as Kaufmann et al. (1999) point out, CV is strongly criticized as a means of estimating precision. In testing precision of the MIM protocol, CV was used to assess differences between repeat samples (repeatability). To incorporate site variability into the assessment of precision, replicate samples were combined to calculate the mean of all observations, and the confidence interval of those combined samples was used to describe range of variability around samples drawn from tests of the same DMA. More details, including results of testing, are presented in appendix F.

B. Training

As with any monitoring protocol, training is required to become proficient in its use. Heitke et al. (2008) concluded that training reduced estimates of observer variability in streambank alteration. Archer et al. (2004) found that with training observer variability could be reduced to less than 20 percent of the total variability for most instream attributes evaluated. Testing of the MIM protocol also indicated lower observer variability for most indicators after training (see appendix F).

C. Interpretation and Evaluation

There is exhaustive literature describing the effects of livestock grazing on streams and riparian vegetation. A few excellent summaries are contained in Platts (1991), Powell et al. (2000), and Wyman et al. (2006). Recognition of cause-and-effect relationships between both the short- and long-term indicators is important. Streambank alteration, for example, influences streambank stability and potentially substrate size distribution. The pathways of effect do not stop there. Loss of streambank stability may result in channel destabilization, channel widening, decreased water velocity, increased water temperature, increased substrate deposition, increased sediment supply, decreased substrate space, and decreased pool depth.

The MIM protocol has been tested at a number of sites to evaluate livestock grazing effects. For the most part, these tests have been conducted where an ungrazed reference site was located in proximity to the grazed site. So far, because of the newness of this protocol, limited data are available to assess trends, and only short-term trends can be assessed. However, the data that are available have been very instructive. The following examples are provided to give some indication of the usefulness of these kinds of data.

1. ***Elk Creek:*** A comparison of metrics for samples taken at the DMA and within an exclosure in 2005 and again at the DMA in 2008 is summarized in table 12. Comparing metrics both within and outside the grazing exclosure helped to determine which factors were most influenced by livestock use in the area. The best short-term indicator was streambank alteration. Woody use and stubble height showed little difference between grazed and ungrazed estimates. As expected, streambank stability differences reflect the influence of streambank alteration on the long-term indicators. Also as expected,

Table 12. DMA and Exclosure Metrics for Elk Creek in 2005 and 2008

Year	Stubble Height (in)		Streambank Alteration (%)		Streambank Stability (%)		Site Wetland Rating		% Hydric Vegetation	
	DMA	Exclosure	DMA	Exclosure	DMA	Exclosure	DMA	Exclosure	DMA	Exclosure
2005	5.1	6.6	40	1	37	85	79	73	72	89
2008	11.2		1		35		61		47	

Year	Greenline-Greenline-to Width		Woody Species Use (%)		% Woody Composition		% Seedlings/ Young		Winward Greenline Stability Rating	
	DMA	Exclosure	DMA	Exclosure	DMA	Exclosure	DMA	Exclosure	DMA	Exclosure
2005	4.7	4.72	59	58.1	5	25	8	97	5.28	6.57
2008	6.27		5		9		0		4.8	

the vegetation indicators do not differ greatly between exclosure and DMA; however, the abundance of woody plants, including the regeneration of saplings and young, was much greater in the exclosure. Because the unit was rested in 2008, stubble heights were much greater and streambank alteration and woody browse were much lower. Yet even though it was rested in 2008, long-term indicators for the unit showed mostly declines as compared with 2005.

2. *Hardtrigger Creek:* Monitoring at the Hardtrigger Creek test site annually from 2005 to 2009 indicated changes due to grazing events in recent years (table 13). In 2005 and 2006, light grazing use was related to good streambank stability, high wetland rating, and riparian vegetation dominated by hydric species. In 2007, a drought year, cattle use concentrated along the stream and resulted in much more streambank trampling and streambank alteration. Consequently, streambank stability declined, as did the wetland vegetation rating and percent hydric vegetation. Although there was some regrowth of residual vegetation, as reflected in the stubble height at the end of 2007, bank conditions did not recover. Streambank alteration and stability were again measured prior to livestock use early in 2008. There had been a partial recovery in streambank stability of 16 percent during that interim period of rest. However, livestock use in 2008 once again altered the streambanks, resulting in a loss of bank stability. Prior to grazing in 2009, streambank stability had recovered substantially from 30 percent in 2008 to 72 percent. These observations suggest the need to assess streambank alteration and streambank stability together and to account for annual streambank stability recovery to assess the effects of streambank alteration.

Table 13. Test Site Data for Hardtrigger Creek between 2005 and 2009 (blank cells denotes no data collected)

Year	Stubble Height	Streambank Alteration	Streambank Stability	Site Wetland Rating	Hydric Vegetation
2005	8″	13%	81%	80	73%
2006	6″	7%	88%	75	59%
2007 Spring	4″	43%	30%	66	41%
2007 Fall	9″	49%	30%		
2008 Before		14%	46%		
2008 After	5″	55%	30%	61	48%
2009 Before		15%	72%		

D. Trend Assessment

When assessing trends, there are two basic questions that need to be answered: 1) can we conclude that significant change has occurred, and 2) can we conclude that there is a difference between population A and population B based on samples drawn from those two populations? Population A represents data collected at a specific time and population B represents data collected at some later time. Answering these questions requires statistical testing. Most of the commonly used tests (e.g., the *t* statistic) are designed for scalar data that fit normal or bell-shaped distributions. For some of the metrics, graphs are provided in the Data Analysis Module to facilitate a first-level assessment of the shape of the distribution. Not all metrics fit a normal probability distribution. Streambank alteration, for example, is heavily skewed to the left (most of the time the majority of samples are 0 or 1, with few higher values). Also some metrics are categorical or ranked data. An example is streambank stability, which is associated with classes. For nonnormal and categorical data, nonparametric statistics are required.

The underlying assumptions associated with parametric statistics are that: 1) the data are normally distributed, 2) the data are taken from a random sample of the population, 3) the observations are spatially and temporally independent, and 4) the errors in the data are randomly distributed. There are statistical tests for all of these assumptions; however, the MIM protocol is designed to obtain random independent samples from a population representing the riparian complex. An excellent summary of statistical tests, including a thorough discussion of power (probability of detecting a change) and the level of significance (probability that a difference is not real but simply due to chance) is contained in MacDonald et al. (1991).

E. Adaptive Management

Williams et al. (2007) defined adaptive management as "a systematic approach for improving resource management by learning from management outcomes." The Department of the Interior (Secretary's Order No. 3270 - superseded 02/01/08 by 522 DM 1) and the U.S. Forest Service (Forest Service Handbook 2209.13, chapter 90, section 92.23b) have adopted policies emphasizing adaptive management in their program and procedural guidance. To be consistent with the agency policies would require developing specific riparian and stream management objectives, a grazing management plan designed to meet those objectives, and short-term and long-term monitoring criteria to evaluate success. Annual monitoring of livestock use helps determine if grazing management is being implemented as planned. Long-term (trend) monitoring is used to determine if resource management objectives are being achieved.

Short-term monitoring of livestock use is generally used in two ways: 1) as trigger indicators; and 2) as endpoint indicators. The short-term indicators (e.g., stubble height, woody species use, streambank alteration) are monitored to help determine when to move the animals to another grazing area. Endpoint indicators of livestock use, also the short-term indicators, are monitored after the end of the growing and grazing season to determine if the use or disturbance was within prescribed levels or to provide a warning that the amount of grazing use or streambank disturbance may prevent the achievement of long-term management objectives. Endpoint monitoring data provide information necessary to evaluate the effect of grazing on long-term trends in stream and streamside riparian habitat conditions.

Annual indicators of use alone do not provide adequate information from which to make good decisions (University of Idaho Stubble Height Study Team 2004). Information about the short-term indicators of livestock use, combined with long-term indicators of condition, is key to identifying cause-and-effect relationships between livestock grazing and stream-riparian function. This information is important for making good management decisions. Because of site and management complexity, it may not be possible to know in advance which indicator(s) best detect management influences on stream and streamside riparian vegetation condition. For that reason, using multiple indicators is suggested as a more complete and useful approach. Once relationships have been established, it may be possible to select the specific indicator(s) that is (are) most effective for detecting change at the site or addressing specific management issues or objectives.

APPENDIX A: GREENLINE EXAMPLES *

Figure A1. The greenline is the first relatively continuous line of perennial vegetation above the water.

Figure A2. Greenlines follow the relatively continuous line of live perennial vegetation with at least 25 percent foliar cover.

* The dashed line shown in some figures represents the greenline.

Figure A3. The greenline cannot exhibit patches of bare ground, litter, or nonvascular plants exceeding 10 by 10 cm or 10 percent of the quadrat. Excessive trampling may cause the greenline to move away from the stream.

Figure A4. Often the greenline is on the edge of the terrace above the water level.

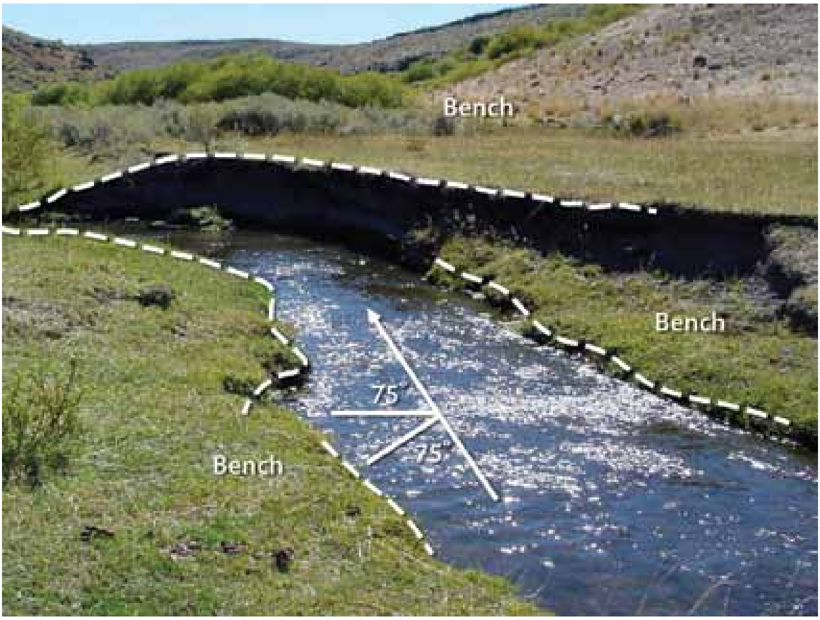


Figure A5. The first bench (floodplain) is the first relatively flat area adjacent to the stream with an abrupt edge going into the water. It is the active floodplain that is frequently flooded. The second bench (terrace) is elevationally higher than the floodplain. The greenline often follows the edge of the floodplain or the terrace edge closest to the stream.

Figure A6. The greenline on the left side of the photo is in two segments, with the lower segment near the water's edge and the upper segment along the edge of the terrace with upland vegetation. The greenline on the right side of the stream is continuous along the perennial vegetation located on a bar.

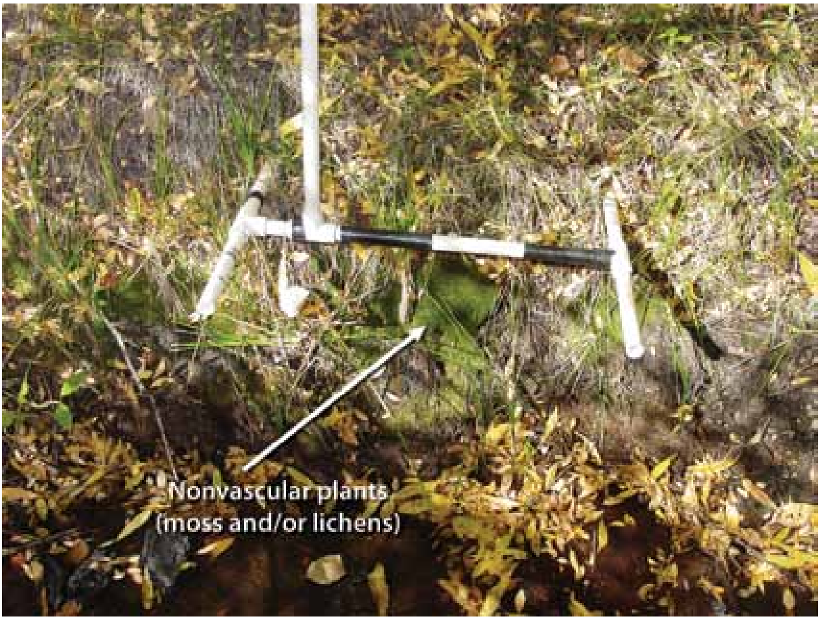


Figure A7. Nonvascular plants such as moss and lichens are not considered part of the greenline.

Figure A8. The greenline must have at least 25 percent cover and there are no patches of bare ground larger than 10 percent of the plot. Area “A” is at least 10 percent; therefore, the monitoring frame is not on the greenline.

Figure A9. Frequently the greenline is near the bankfull stage. The greenline is located upslope of vegetation closer to the waterline because that vegetation has less than 25 percent foliar cover.

Figure A10. When mature trees and shrubs are present and there is no understory beneath the canopy, the greenline is located by drawing a line connecting the base of the plants on the stream side.

Figure A11. When under a tree or shrub canopy (within the drip line), the greenline is on a line between two woody species, tree or shrub.

Figure A12. High waterflow obscures the vegetation, floodplain, and channel characteristics needed to obtain an accurate sample. Sampling should be avoided when the greenline is flooded.

Figure A13. The greenline is located along the edge of the water line when vegetation is growing in shallow water. The inset picture shows spikerush (*Eleocharis* sp.) growing in shallow water along the margin of the stream. Photo - PIBO, U.S. Forest Service.

Figure A14. The greenline follows the sedge (*Carex* sp.) or the edge of the water if the sedge is in the water. Floating plants such as speedwell (*Veronica* sp.) and watercress (*Rorippa nasturtium-aquaticum*) are not considered part of the greenline. Photo - PIBO, U.S. Forest Service.

Figure A15. Coyote willow (*Salix exigua*) spreads by rhizomes. At times, it will sprout within the stream channel on streams that have very low or no flow during part of the growing season. When this occurs, the greenline is along the edge of the water . When plants occupy the entire channel, the greenline is down the thalweg of the channel. Measure streambank alteration at the edge of the first bench or, when a bench is not evident, at the waterline. Photo - PIBO, U.S. Forest Service.

Figure A16. Exposed live shrub or tree roots are part of the greenline.

Figure A17. Watercress (*Rorippa nasturtium-aquaticum*) is not considered part of the greenline. It should be noted in the remarks section of the data worksheet in the Data Entry Module.

Figure A18. The greenline follows the sedge (*Carex* sp.) on each side of the stream. Water speedwell (*Veronica anagallis-aquatica*) growing in the stream is not part of the greenline. Photo - PIBO, U.S. Forest Service.

Figure A19. Brookgrass (*Catabrosa aquatica*) is a short-lived perennial grass that occasionally grows on the streambank. It grows mostly in the margin of a stream. It is not considered part of the greenline unless rooted above the scour line on the streambank.

Figure A20. Rock "A" is embedded and above the scour line. Active erosion exists on the streambank side of rock "B," and it is below the scour line.

Figure A21. This complex greenline includes vegetation, embedded rock, and anchored wood. Segment "A" is embedded rock and segment "B" is anchored wood. Both rock and wood are above the scour line.

Figure A22. When a logjam that crosses the stream is encountered, the greenline continues over the logjam and is recorded as anchored wood. Photo - PIBO, U.S. Forest Service.

Figure A23. Slump blocks along the far streambank are not attached by vegetation to the terrace wall and therefore are not part of the greenline. Photo - PIBO, U.S. Forest Service.

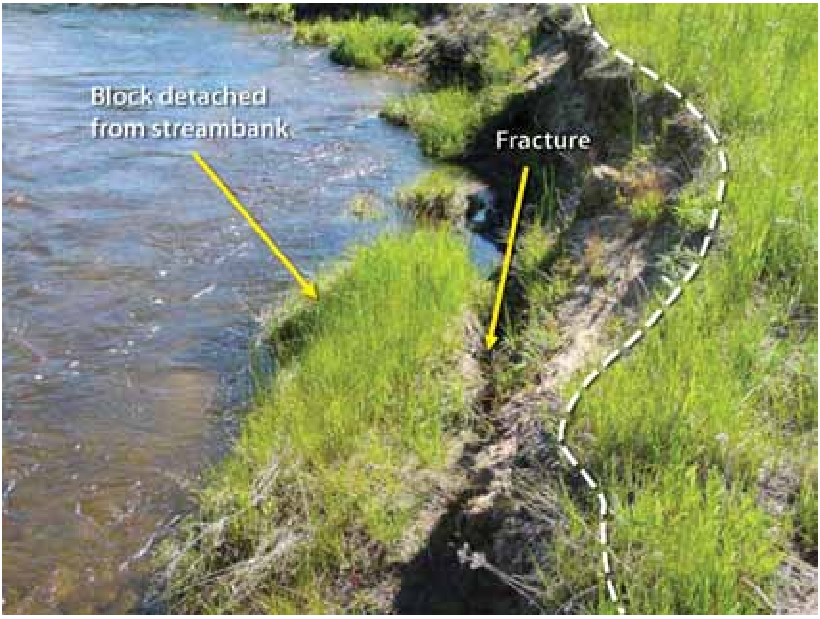


Figure A24. The slump block is detached from the bank wall and there is an obvious fracture between the slump block and the streambank wall. The greenline is located on the streambank as shown.

Figure A25. The greenline follows the continuous line of vegetation. Note the blocks that have fallen into the stream channel and the blocks that are broken from the bank but have not fallen into the stream. The greenline is located behind the broken bank.

Figure A26. The greenline follows the outer streambank greenline. It does not cross the small channel running along the left of the island. Photo - PIBO, U.S. Forest Service.

Figure A27. The vegetation patches ("A") are considered islands because the scoured channels ("B") do not have perennial vegetation growing across them.

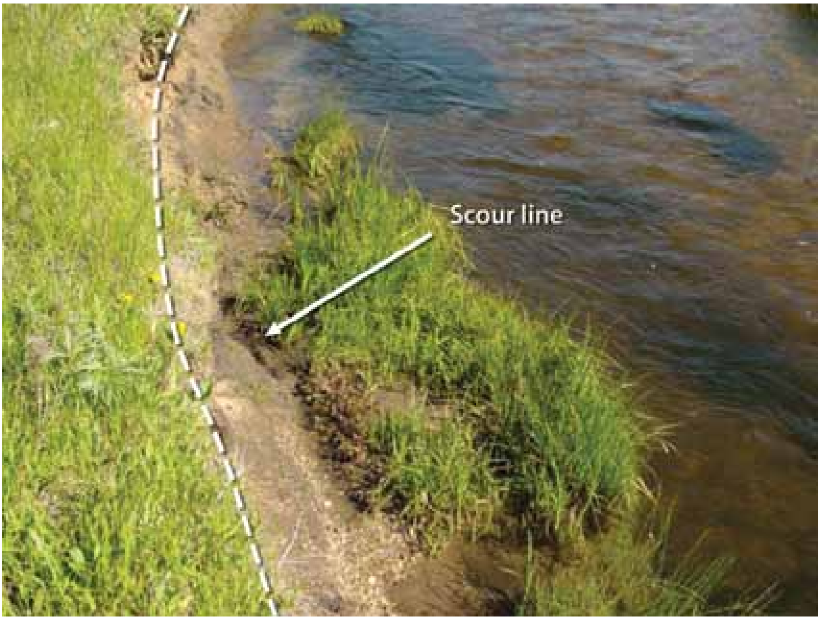


Figure A28. Vegetation is not well established between the slump block and the vertical bank, creating a scour line between the vegetation block and the streambank. This block is considered an island.

Figure A29. When no greenline is present within 6 meters of the water's edge, record "NG."

APPENDIX B: RECORDING FIELD DATA

Multiple Indicator Monitoring Field Data Sheet—Part 1, Site Information

Allotment	Forest/District	Ranger District/Field Office	Observers	Date
DMA ID	Stream Name	DMA Name and/or Description		

Step Interval	Step Length (m)	Sample Interval	Stream Gradient	Substrate	Stubble Height Recorded in (I) inches or (C) centimeters	Plant Region	Subwatershed (6th Field HUC)

Downstream Marker		Upstream Marker		Reference Marker	
Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
Zone	UTM	UTM		UTM	

Woody Species			
1. Are woody plants supposed to be present at this site? (Y/N)		2. Are there any hydric woody plants present? (Y/N)	
3. Are all age classes of hydric woody plants present? (Y/N)		Comments:	
DMA Site Selection Criteria			
1. Was the riparian complex selected by an interdisciplinary team? (Y, N, or N/A)		2. Is the DMA in a riparian complex that represents management activity and is accessible to the activity? (Y, N, or N/A)	
3. Is the DMA randomly located in the riparian complex most sensitive to management? (Y, N, or N/A)		4. Is the DMA sensitive to disturbance (not armored)? (Y, N, or N/A)	
5. Will the DMA site respond to management? (Y, N, or N/A)		6. If the stream is over 4 percent gradient, does it have a well-developed floodplain? (Y, N, or N/A)	
7. Is the DMA located outside of a livestock concentration area? (Y, N, or N/A)		8. Is the DMA free from the influence of compounding activities? (Y, N, or N/A)	
Is it a critical DMA? (Y or N)		Is it a reference DMA? (Y or N)	

Narrative:

Photo Log	File name			
	Lower Across	Lower Upstream	Upper Across	Upper Downstream

Multiple Indicator Monitoring Field Data Sheet—Part 2

Page _____ of ______

DMA:	Allotment:	Pasture:	Stream:	Date:

Plot No.	Greenline Composition		Woody Species Height Class (1 to 6 or blank)	Streambank				Stubble Height		GGW (0.1 m)	Woody Species Age Class					Woody Species Use	
					Stability												
	Species/Rock/ Wood	Percent		Alteration (0 to 5)	Erosional/Depositional (E/D)	Covered/Uncovered (C/U)	Stability (F, S, SL, E, A)*	Species	Height (cm/in)		Species	Seedling (no.)	Young (no.)	Mature (no.)	Rhizome (1/blank)	Species	Use (midpoint)

*F-fracture, S-slump, SL-slough, E-eroding, or A-absent

Note: Usually eight Field Data Sheets, Part 2, are needed for each monitoring site.

Multiple Indicator Monitoring Field Data Sheet—Part 3, Substrate

DMA:	Allotment:	Pasture:
Stream:	Date:	Used Gravelometer (Y or N)?

Plot No.	Pebble (mm)										Notes
	1	2	3	4	5	6	7	8	9	10	
2											
4											
6											
8											
10											
12											
14											
16											
18											
20											
22											
24											
26											
28											
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42											
44											
46											
48											
50											
52											
54											
56											
58											
60											

Multiple Indicator Monitoring Field Data Sheet—Part 4, Residual Pool Depth and Pool Frequency

DMA:

Allotment:

Pasture:

Stream:

Date:

Distance between riffle crest and pool bottom	Depth of riffle crest or pool bottom	Riffle crest (R) or pool bottom (P)	Distance between riffle crest and pool bottom	Depth of riffle crest or pool bottom	Riffle crest (R) or pool bottom (P)
■		R			R
		P			P
		R			R
		P			P
		R			R
		P			P
		R			R
		P			P
		R			R
		P			P
		R			R
		P			P
		R			R
		P			P
		R			R
		P			P
		R			R
		P			P
		R			R
		P			P
		R			R
		P			P
		R			R
		P			P
		R			R
		P			P
		R			R
		P			P
		R			R
		P			P
		R			R
		P			P

Multiple Indicator Monitoring Field Data Sheet—Part 5, Comments

DMA:		Allotment:
Pasture:	Stream:	Date:

Plot No.	Narrative

APPENDIX C: EQUIPMENT

The following equipment is needed to complete the MIM protocol:

1. Waders or wading shoes are useful. It is easier to monitor most streams by pacing in the stream rather than on the streambank.
2. Laser rangefinder, measuring rod, or tape measure (metric preferred).
3. Handheld computer (PDA) with the Microsoft Excel spreadsheet from the Data Entry Module uploaded. Extra batteries or extended life batteries are required.
4. MIM Field Data Sheets (if not using field computer or data recorder).
5. Global positioning system (GPS) receiver with extra batteries.
6. Appropriate plant identification keys for riparian plants.
7. MIM monitoring frame is shown in figure C1. Construct the monitoring frame prior to going to the field. It can be constructed from the materials in table C1 and the instructions that follow.

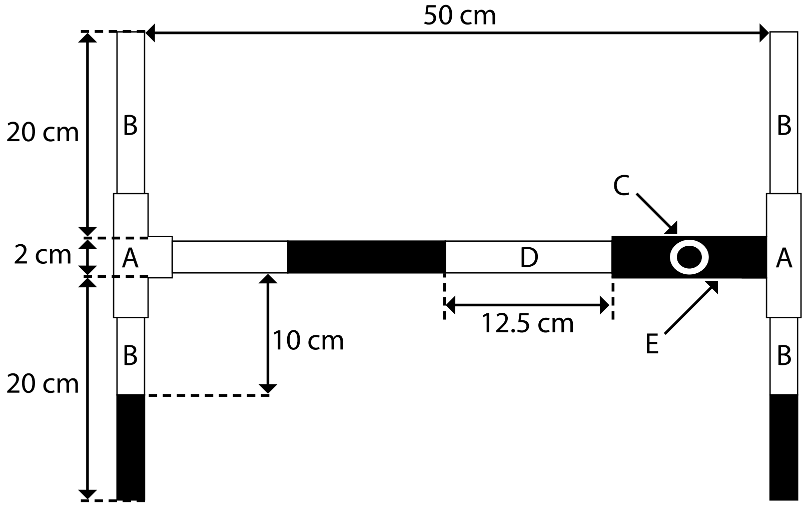

Figure C1. Monitoring frame.

Monitoring frames may be constructed of various materials including metal (usually aluminum) or 1/2-inch PVC schedule 40 plastic pipe. Metal frequency plot frames (typically 40 by 40 cm) may be used by extending the tines to 50 cm in length and marking the four incremental segments with lines or alternating colors.

Schedule 40 PVC is rigid and does not warp as much as lighter pipe. This material is inexpensive, light, and easy to use to make the frames. Carefully measure each of the products before they are glued together as fittings (tees) are not uniform among manufacturers. To construct a monitoring frame using 1/2-inch PVC pipe:

a. Cut pipe to the appropriate lengths (see table C1).

b. Apply PVC cement to one end of pipe part B and the tee (part A) and slide them together. Repeat the procedure on the opposite end of the tee. Repeat the process on the second tee (part A). Remember PVC cement cures rapidly **(within a few seconds). There are no second chances.**

c. Apply cement to the short pipe (part E) and the tee of one of the previously constructed parts (see b). Slide them together.

d. Apply cement to the tee (part C) and the end of part E. Slide the two parts together, making sure the tee is perpendicular to part A so that the handle can be used properly.

Table C1. Monitoring Frame Material List

Item	Part Label	Number	Length*	
			Inches	Centimeters
½-inch tee (3 slip joints)	A	2	--	--
PVC pipe (Schedule 40)	B	4	7.75	19.7
½-inch tee (2 slip joints and 1 treaded female joint)	C	1	--	--
PVC pipe (Schedule 40)	D	1	16 .9	43
PVC pipe (Schedule 40)	E	1	1.25	3.2
PVC pipe (handle)	F	1	39	100
½-inch threaded coupler (male)	G	1	--	--
PVC cement	--	--	--	--
Colored electrical tape	--	--	--	--
Teflon tape	--	--	--	--

*Cut the pipe into the lengths listed as the tees will add the required length.

e. The center pipe (part D) may or may not be glued into place between the previously constructed parts. If the center pipe is glued, make sure the two ends are level. Not gluing the center pipe allows the frame to be taken apart and transported. On the other hand, it may come apart occasionally when being used.

f. Construct the handle (figure C2) by cementing the male threaded connector (part G) to one end of the pipe (part F). Put Teflon tape on the threads prior to screwing the parts together, which makes it much easier to remove the handle when needed.

g. Screw the handle into the frame and mark the handle in 1-in (or 2-cm) increments beginning at ground level. Proceed up the handle for 1 m. Cut off excess material.

h. The markings on the frame provide references for observers to project lines and estimate the amount of vegetation in the quadrat. Electrical tape wrapped around the pipe is a good material for marking the alternating colors. Tape does not come off the pipe as easily as paint does.

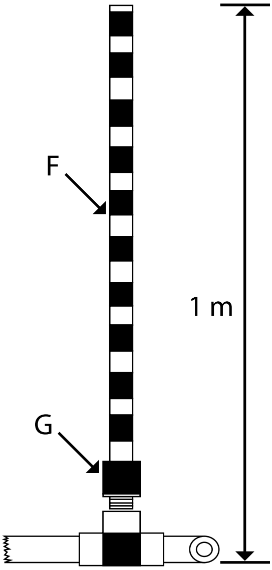

Figure C2. Monitoring frame handle.

APPENDIX D: STREAMBANK ALTERATION EXAMPLES*

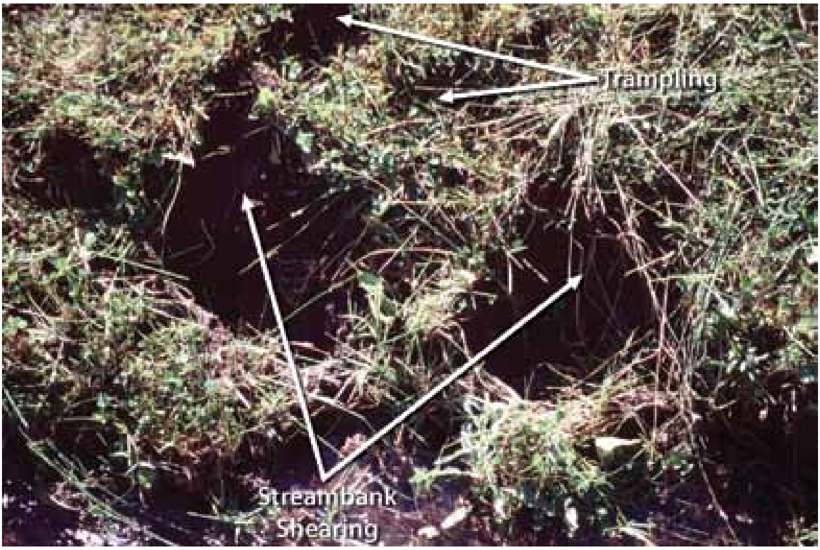

Figure D1. Disturbance is considered trampling when a track caused by a large herbivore exposes at least 13 mm (1/2 inch) of bare soil.

Figure D2. The monitoring frame is centered on the greenline and the number of lines (0 to 5) that intersect streambank alteration (trampling or shearing) is counted and recorded. Lines 1, 2, 3, 4, and 5 intersect streambank alteration. A "5" is recorded.

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* The dashed line shown in some figures represents the greenline.

Figure D3. When livestock trails occur within the DMA, they are considered for streambank alteration. The example above shows the frame is moved perpendicular to the stream until the rules for greenline have been met. Part of the frame (below the terrace) is over the trail that has been recently used by livestock so a "5" is recorded.

Figure D4. This example is heavily trampled and all five lines intersect streambank alteration. A "5" is recorded.

Figure D5. Trampling on the terrace is not recorded as streambank alteration. Alteration is only recorded if it occurs on the steep face of the bank. The lines are projected for the greenline down the bank, within the monitoring frame. In the example above, line 1, nearest the handle, does not intersect alteration. Lines 2 through 5 intersect shears so a “4” is recorded.

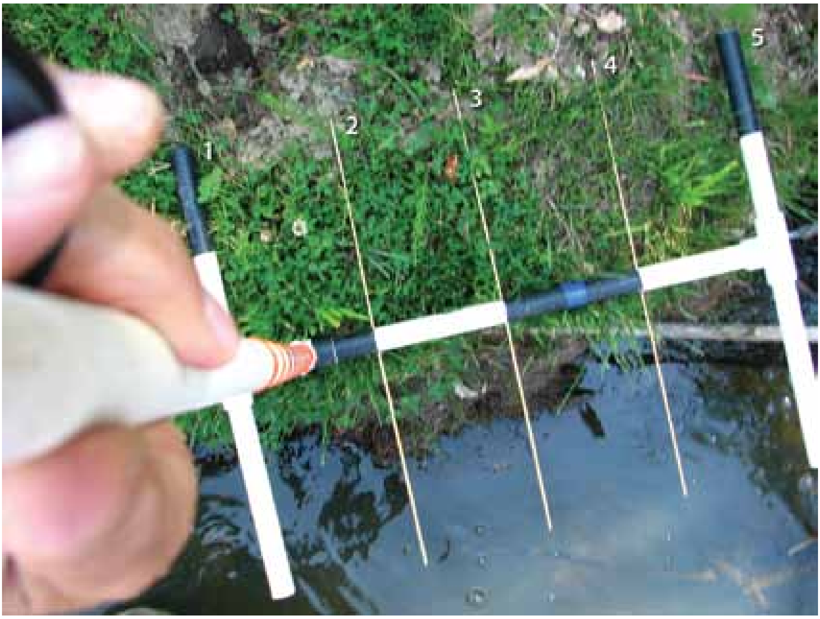

Figure D6. Lines 1, 2, and 4 intersect streambank alteration. A “3” is recorded.

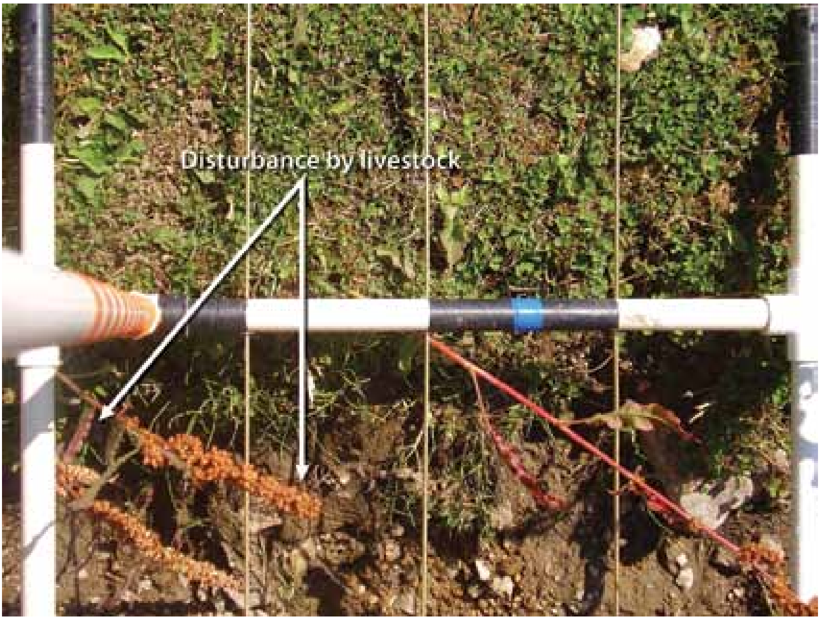

Figure D7. Livestock have caused alteration at lines 1 and 2. A "2" is recorded.

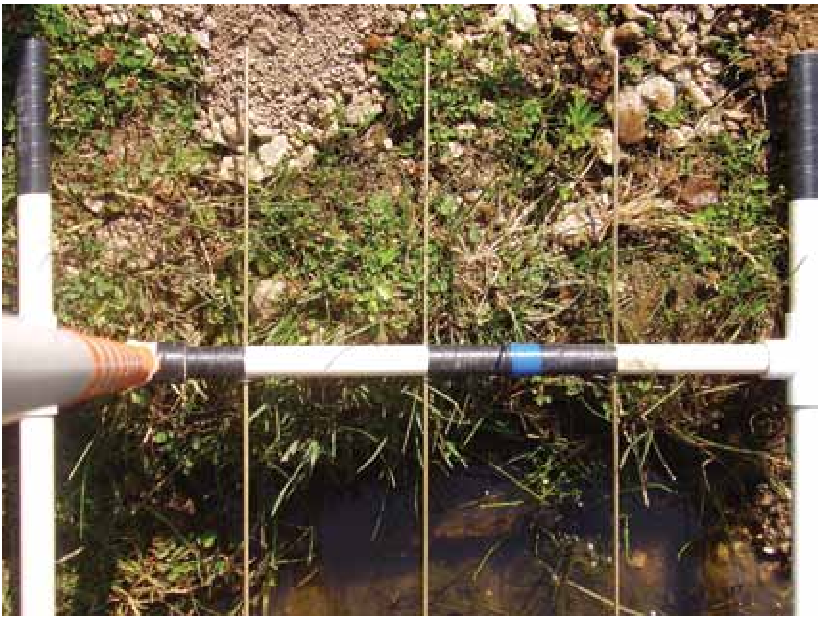

Figure D8. No streambank alteration is obvious. A zero is recorded.

APPENDIX E: STREAMBANK STABILITY AND COVER EXAMPLES

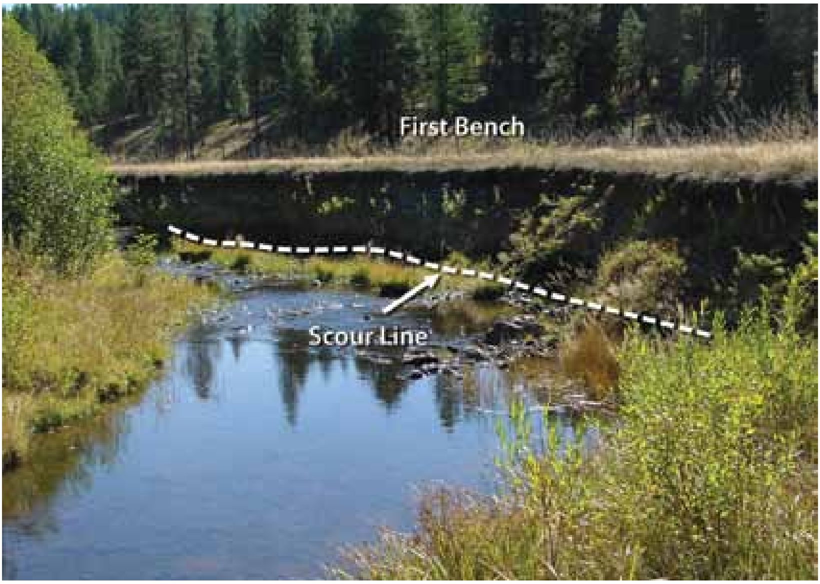

Figure E1. The first bench is the first relatively flat area above the scour line or edge of the water. An abrupt steep face from the edge of the bench to the scour line is characteristic of a "cut bank." Slough from the bank wall has direct access to the stream. Vegetation in the channels forms islands.

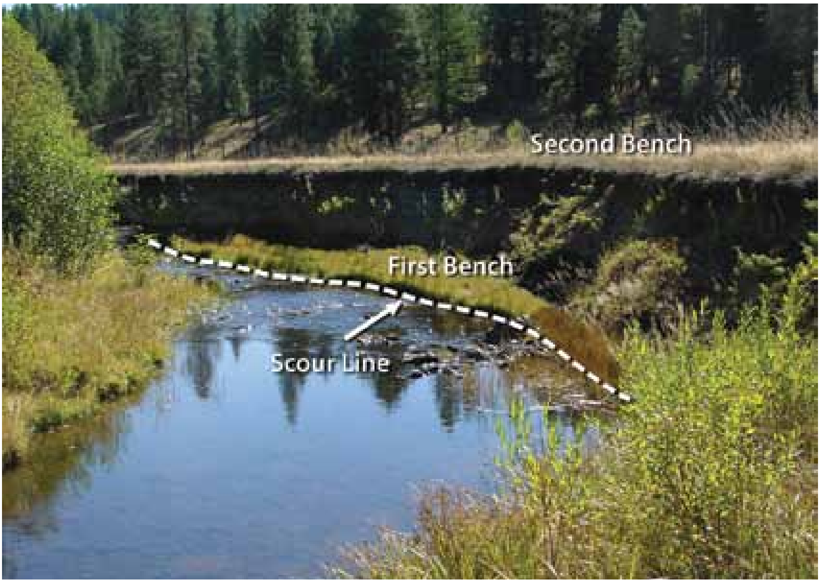

Figure E2. A new floodplain has developed creating the first bench at a lower elevation. Slough from the second bench does not go directly into the stream, as it is filtered by the first bench or new floodplain.

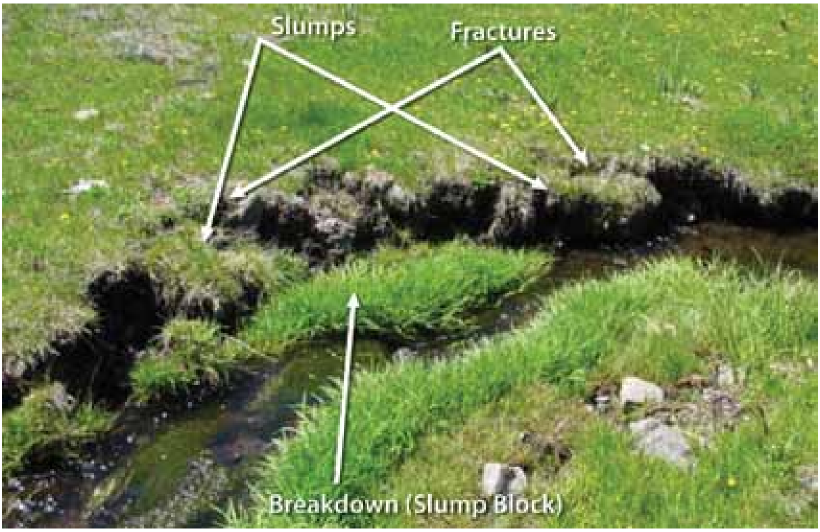

Figure E3. Erosional features help determine the stability of a streambank. Slump blocks that are detached from the streambank and now isolated to the channel are not considered part of the streambank. Slumps must be obviously sliding down but still attached as part of the streambank. Fractures must be obvious at the top of the streambank or on the bench.

Figure E4. This large fracture has at least 50 percent vegetation cover and is thus recorded as erosional (E), covered (C), and fracture (F).

Figure E5. The stream in this photo is flowing at the scour line. The streambank is erosional (E) and slump (S) is recorded.

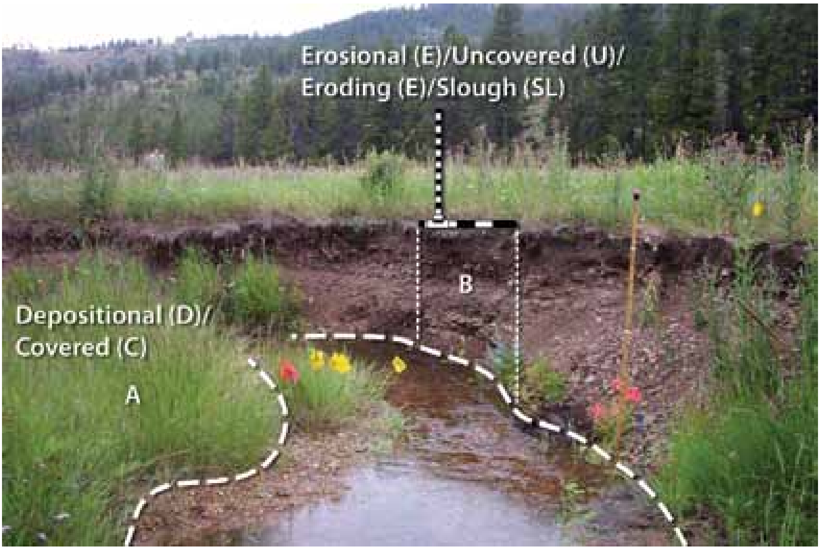

Figure E6. The dashed line represents the scour line. "A" is a point bar; therefore, it is depositional (D) and covered (C). "B" shows the length of streambank evaluated. The streambank evaluated is erosional (E), uncovered (U), and eroding (E) or slough (SL). Photo - PIBO, U.S. Forest Service.

Figure E7. The left streambank is a point bar that is depositional (D) and covered (C). Slump blocks on the right bank are mostly covered with vegetation and are still attached to the streambank above the scour line and therefore are recorded as erosional (E), covered (C), and slump (S). The dashed line is the greenline. Photo - PIBO, U.S. Forest Service.

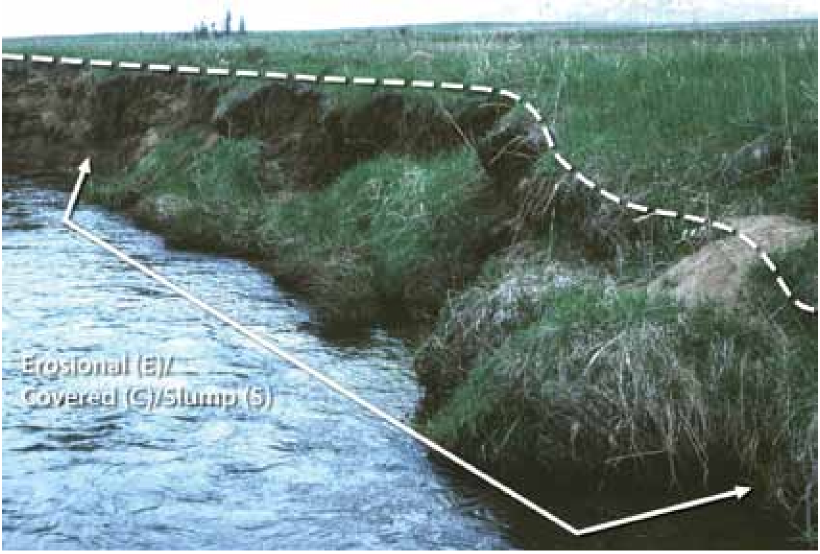

Figure E8. Slump blocks and slumping banks covered with vegetation are recorded as erosional (E), covered (C), and slump (S). The dashed line is the greenline.

Figure E9. Four different conditions are shown at this location. The left side is an outside bend that is erosional (E), with no vegetation, rock, or wood cover (U), and slough (SL) directly entering the stream. The upper middle section is an erosional (E) streambank, uncovered (U) with slump (S). The upper right section is a streambank that has slumped in the past and is reattached, so it is recorded as erosional (E), covered (C), erosional activity absent (A). The lower right streambank is a point bar that is depositional (D) and covered (C).

Figure E10. The dashed line represents the scour line. The streambank on the left side of the stream is an erosional bank (E) that is uncovered (U) and eroding (E), and the other side is depositional (D) and covered (C).

Figure E11. The streambank has an obvious scour line. The bank evaluated is above the scour line to the first bench and is recorded as erosional (E), uncovered (U), and eroding (E) or slough (SL).

Figure E12. The streambank is erosional (E) and not covered with vegetation, rock, or wood. It has a bank angle of more than 10 degrees (22 percent) from vertical with no bench to capture the sediment, and thus the sediment enters directly into the stream as slough; therefore, it is recorded as uncovered (U) and slough (SL).

Figure E13. Trampling by large herbivores has caused obvious "slumping." The slump is greater than one-fourth of the plot length and is recorded (S).

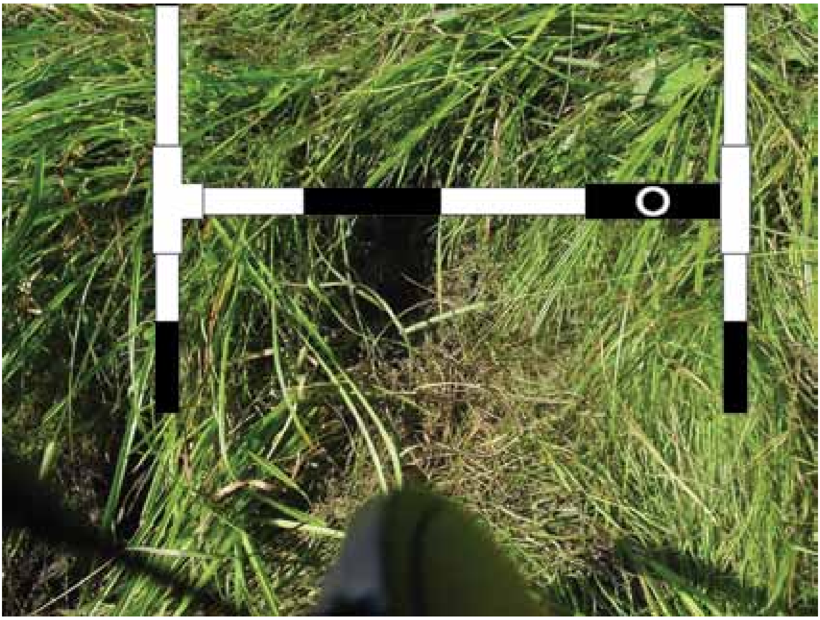

Figure E14. There is a hoofprint in the bank, but no slump or slough is associated with the hoofprint; therefore, there is no indicator of instability so covered (C) and absent (A) are recorded.

APPENDIX F: TESTING PRECISION AND ACCURACY AND DETECTING CHANGE

To be useful and effective, results of monitoring should reflect a reasonable degree of precision and accuracy and be responsive to factors that affect the ability to detect change for each monitoring indicator. Precision is the closeness of repeated measurements of the same indicator, and accuracy is the closeness of a measurement to its true value (Elzinga et al. 1998). The ability to detect change depends to a large degree on the accuracy and precision of the measurement protocol. Studies of stream-habitat-related monitoring variables have shown that indicators that rely upon visual estimates, while attractive because of their rapidity, have low precision (Kaufmann et al. 1999). Precision is related to sample size, natural variability in the parameter, level of statistical significance, statistical power, and the level of observer bias in the method itself (MacDonald et al. 1991). Because estimates of trend are made at each individual DMA, the principal sources of variability in sampling indicators are associated with measurement error (differences between repeat observations) and spatial variability within the DMA. If resampling is not always done at the low streamflow time of year, additional sources of temporal variability may be introduced. The MIM protocol has been designed so as to limit dependency upon streamflow. Still, some short-term climatic influences, such as a sudden cloudburst during the low-flow season, may introduce variation that must be accounted for. A reference reach subject to the same kinds of temporal variations is desirable in the latter case. The following describes how precision and accuracy were evaluated in testing this protocol.

Precision: Imprecision, or the difference between repeat samples, arises from the bias of individual observers. It is critical to minimize the subjectivity associated with monitoring to reduce observer bias and to maximize precision. In a study of the precision of stream habitat measurements, Kaufmann et al. (1999) concluded:

> “Measurements are more precise than visual estimates, but carefully-designed visual estimation procedures can be nearly as precise as measurements. To enhance precision, these visual observations are limited to measurable characteristics (e.g., cover or presence), rather than judgements of habitat quality, and they are made at multiple locations within a reach.”

Every effort has been made in the MIM protocol to ensure that visual observations are measurable. If a substantial amount of bias in sampling occurs, results may be imprecise and not useful for detecting change and/or compliance with specific targets for the indicator (Elzinga et al. 1998). With respect to compliance, for example, if the stubble height allowable use criterion is 4 inches and the precision of the measurement is 0.96 inches, an observation of 3.6 inches would not imply that the criterion was exceeded. With respect to trend, if the objective for streambank stability is to achieve 80 percent streambank stability and the precision is 8 percent, an observation of 85 percent does not mean that the objective has been met.

The coefficient of variation, a dimensionless index of variability between and among observers' repeated samples, has been used to estimate precision (Kauffman et al. 1999, Coles-Ritchie et al. 2004, Heitke et al. 2008, and Roper et al. 2002). The CV is calculated as follows:

CV = sq root (crew variance)/mean*100

Where:

CV = the coefficient of variation

Crew Variance = variance on repeat samples

Mean = the mean value of the repeat samples

The CV may be expressed as a percentage and represents a proportion of the mean. If the square root of crew variance (standard deviation) is less than 20 percent of the mean (CV < 20), then by comparison, a CV of 30 would be less precise. For purposes of these tests, CV values greater than 20 and less than 33 are considered moderately precise, and values less than 20 are considered precise (Kaufmann et al. 1999). Kaufmann et al. (1999) were interested in detecting change by pooling data across many streams in a region. With the MIM protocol, the observer is more concerned with detecting change at a single site. For this reason, CV was examined site-by-site and not pooled regionally.

Values of CV less than 10 may be required to detect change for variables that may change slowly through time (vegetation erosion resistance, for example). Conversely, substrate values of CV less than 25 may be adequate for detecting change in variables more responsive to management, such as greenline-to-greenline width or percent streambank stability (Archer et al. 2004).

Three different approaches have been used to assess the precision of MIM metrics. In the first approach, several test sites were established in Idaho and monitored over the years as part of the development of the MIM protocol. Repeat tests between and among the observers were used to evaluate precision at a limited number of sites (5). In the second approach, a much larger sample (30 sites) was obtained involving participants in a number of regional training sessions at many locations in the Western United States over several years. Observers were instructed to repeat observations immediately after obtaining their first sample set to obtain a replicate using the same observers. The instructors would also sample the same reach to evaluate replication by different observers. It has been suggested that this approach may be biased by the fact that observers made the estimates at the same time they were learning the protocol. Such bias may result in better agreement, due to the immediacy of the training, or worse agreement, due to lack of experience with the rule sets. Also, this approach does not account for "revisit variance" across the sample season, which accounts for differences that may result from natural changes during that time period. In particular, streambank alteration and stability may change between the time grazing ends and the end of fall or onset of winter. Vegetation variables would not be expected to change dramatically during the sample season; however, the ability to identify plants could vary depending upon the presence of reproductive structures.

To further address revisit variance, in the third approach, a more controlled experiment was established to evaluate the variability among trained observers, consisting of three separate teams that visited eight monumented sites (PIBO sites) at different times in the same sampling season (late summer). Teams visited the sites at varying times within a 2-month period during the low-flow season and independently relocated the sites. The advantage of these tests is that opportunities for assessing variation due to site revisits and within-seasonal variations are better. Results of these tests are presented in table F1. Differences among observers were often greatest at the authors' test sites where indicators were being tested early in the development of the protocols and prior to refinements that included more detailed procedures. Training sites also tended to have higher differences as compared to the more controlled repeat sites likely because observers were not as proficient in the procedures and other details of the protocols.

Table F1. Mean Difference Among Observers at Authors' Test Sites, at Training Sites, and at the PIBO Repeat Sites

Metric	Test Sites (5)	Training Sites (30)	PIBO Repeat Sites (8)	All Sites
Average Stubble Height for All Species (in)	0.75	0.88	na*	0.86
Streambank Alteration (%)	10.12	6.21	na	6.76
Woody Use All Species (%)	24.49	5.05	na	8.00
Streambank Stability (%)	8.82	8.16	5.61	8.23
Streambank Cover (%)	10.24	8.29	5.43	8.51
Percent Young	14.27	14.47	9.96	14.44
Percent Mature	15.00	14.18	9.44	14.30
Hydric Plants (%)	10.26	6.22	8.84	6.66
Winward Stability Rating (1-10)	0.97	0.42	0.50	0.48
Greenline Ecological Status (1-100)	14.20	10.51	6.93	10.93
Site Wetland Rating (1-100)	5.46	3.76	4.09	3.94
Greenline-to-Greenline Width (m)	0.26	0.46	0.62	0.43
Woody Composition (%)	4.37	8.95	10.51	6.09
Hydric Herbaceous (%)	11.55	8.00	4.58	9.97
Average Height of Dominant Key Species (in)	1.20	1.47	na	1.44
Percent Fines	2.52	5.09	na	4.72
Median Particle Size (phi)	0.11	na	na	0.11
Pool Frequency (pools per mile)	na	22	na	22
Mean Residual Pool Depth (m)	na	0.01	na	0.01

* na: not available–data not collected.

Precision was also evaluated within and among observers to determine if same observer replicates would be less biased than those of different observers. Table F2 summarizes the coefficients of variation for same and different observers.

Table F2. Percent Agreement and Coefficients of Variation (square root of crew variance divided by the mean times 100) for Repeat Sampling (observer agreement/variation)

Metric	Agreement for categorical variables	CV same observers (30)	CV different observers (33)
Average Stubble Height for All Species (in)		10%	15%
Streambank Alteration (%)		18%	27%
Woody Use All Species (%)		23%	52%
Streambank Stability (%)	81%		
Streambank Cover (%)	85%		
Percent Seedlings + Young		20%	32%
Percent Mature			32%
Hydric Plants (%)	82%		
Winward Stability Rating (1-10)	88%		
Greenline Ecological Status (1-100)	74%		
Site Wetland Rating (1-100)	77%		
Greenline-to-Greenline Width (m)		6%	8%
Woody Composition (%)	79%		
Hydric Herbaceous (%)		17%	38%
Average Height of Dominant Key Species (in)	17%	17%	23%
Percent Fines		7%	6%
Median Particle Size (phi)		5%	23%
Pool Frequency (pools per mile)			13%
Mean Residual Pool Depth (m)			13%

For categorical variables, agreement matrices were used to estimate observer agreement and differences by comparing rating results among repeat tests of the same DMAs. Table F3 describes the results of that analysis for ecological status.

Table F3. Agreement Matrix for Ecological Status (units within each cell represent the rating comparison from the test samples; e.g., 16 repeat tests agreed with an early ecological status rating)

Agreement Matrix - Ecological Status					
	Very Early	Early	Mid	Late	PNC
Very Early	7	1	0	0	0
Early		16	10	2	0
Mid			16	5	0
Late				14	1
PNC					1
# Tests: 73					
Agreement: 74%					

Some variables are measured or estimated at each sample point, including stubble height, streambank alteration, greenline-to-greenline width, woody use, and substrate particle sizes. At the replicate test sites, monitoring indicators were recorded for the reach and revisits or resamples again recorded the same indicators. Because individual sample locations depend on the randomly selected starting point, revisit samples were likely not located at the same plot location. The combined standard deviations for all replications in a reach were then analyzed for sample standard deviation and 95 percent confidence intervals as presented in tables F4 and F5. By combining both site and revisit variability, these confidence intervals, or ranges of variation, are used to estimate the level of change that can be detected over time.

Table F4. Sample Size (N), Standard Deviation (SD), and 95 Percent Confidence Intervals (CI) for Substrate Particle Sizes from the Raw Data and Replicates

Stream Reach	Substrate Particle Size (phi Φ)		
	N	SD	CI
Hardtrigger, Idaho, 08	400	2.4	0.24
Blanchard, Montana, 08	390	1.5	0.17
Fawn, Idaho, 08	400	1.7	0.17
Willow, Idaho, 07	600	2.1	0.17
Mean	**448**	**1.9**	**0.2**
Median	**400**	**1.9**	**0.2**

Table F5. Sample Size (N), Standard Deviation (SD), and 95 Percent Confidence Intervals (CI) for Four Greenline Metrics Using All Samples and Replicates

Stream Reach	Stubble Height (inches)			Greenline-to-Greenline Width (m)			Streambank Alteration (%)			Woody Species Use (%)		
	N	SD	CI	N	SD	CI	N	SD	CI	N	SD	CI
Hardtrigger 08	74	2.3	0.53	135	0.85	0.1	125	33.8	5.9	32	28.1	9.7
Long Tom 1	46	3.4	0.99	81	0.94	0.2	80	36.8	8.1	21	1.1	0.5
Long Tom 2	41	2.5	0.76	95	0.87	0.2	103	30.3	5.8	122	27.5	4.9
Long Tom 5	58	1.4	0.37	89	2.0	0.4	89	23.4	4.9	82	17.1	3.7
Long Tom 6	70	2.8	0.66	87	0.97	0.2	87	31.4	6.6	262	28.2	3.4
NFHUM 1				80	1.17	0.3	80	40.7	8.9	32	21.1	7.3
NFHUM 2	25	5.1	2.01	74	2.25	0.5	80	26.2	5.7			
NFHUM 4	68	1.4	0.34	80	1.39	0.3	81	33.7	7.3	26	32.7	12.6
Big Elk	107	3.2	0.61	130	1.34	0.2	132	35.3	6.0	30	29.1	10.4
Deadwood				250	10.1	1.3				150	2.3	0.4
Falls				229	1.34	0.2						
Fawn				269	1.51	0.2						
Morse				238	6.91	0.9						
Panther				245	0.71	0.1						
Pass				245	0.79	0.1						
Pine				214	1.57	0.2						
Hardtrigger 06	139	3.14	0.52	257	0.72	0.1	254	16.8	2.1	72	2.4	0.5
Marks RF1	79	1.5	0.33	43	1.76	0.5	81	2.2	0.5	15	12.9	6.5
Marks RF2	61	9.05	2.27	69	0.93	0.2	69	2.4	0.6	30	3.7	1.3
Marks 1	33	5.73	1.95	43	1.25	0.4	45	32.2	9.4	7	7.6	5.6
Marks 9	78	9.21	2.04	86	0.96	0.2	85	9.5	2.0	41	21.8	6.7
Marks 10	60	5.98	1.51	76	1.08	0.2	44	1.5	1.2			
Marks 11	46	2.54	0.74	69	1.51	0.4	69	18.8	4.4	8	19.8	13.7
Marks 12	66	0.79	0.19	30	1.11	0.4	27	19.9	7.5	15	30.6	15.5
Haynes 1				50	1.14	0.3	49	25.9	7.3	7	9.8	7.2
Haynes 2	44	3.6	1.07	56	1.01	0.3	55	33.9	9.0	27	25.8	9.7
Haynes 3				48	1.14	0.3	47	27.3	7.8	46	28.1	8.1
Haynes 4				37	1.45	0.5	36	35.2	11.5	52	19.3	5.2
Haynes 5	17	2.7	1.3	55	0.84	0.2	55	30.9	8.2	37	36.6	11.8
Haynes 6	20	1.3	0.59	61	1.63	0.4	57	38.0	9.9	29	14.3	5.2
Shoshone 1	46	3.0	0.86	76	1.77	0.4	78	24.8	5.5	78	0.6	0.1
Shoshone 2				67	0.91	0.2	69	20.9	4.9	48	4.0	1.1
Shoshone 3	24	3.0	1.21	108	2.25	0.4	108	21.2	4.0	62	6.0	1.5
Shoshone 4	41	2.4	0.73	74	2.05	0.5	75	26.3	6.0			

Table F5. Sample Size (N), Standard Deviation (SD), and 95 Percent Confidence Intervals (CI) for Four Greenline Metrics Using All Samples and Replicates continued.

Stream Reach	Stubble Height (inches)			Greenline-to-Greenline Width (m)			Bank Alteration (%)			Woody Use (%)		
	N	SD	CI	N	SD	CI	N	SD	CI	N	SD	CI
Shoshone 5	52	3.4	0.92	55	2.2	0.6	55	32.1	8.5			
Shoshone 6	29	2.2	0.8	67	2.74	0.7	70	37.2	8.7	38	17.6	5.6
Shoshone 7				70	0.99	0.2	69	17.9	4.2	36	5.6	1.8
Shoshone 8	36	2.1	0.68	84	0.94	0.2	84	21.3	4.6	46	11.0	3.2
Shoshone 10	20	2.1	0.92	110	1.25	0.2	124	21.6	3.8	54	10.4	2.8
Range			0.2-2.3			0.1-1.3			0.5-11.5			0.1-15.5
Mean			0.96			0.3			6.0			5.7
Median			0.78			0.3			5.9			5.2

Sample Size Analysis: Another indicator of precision is often called the "bias" in statistics. Bias is the difference between the population mean of a measured indicator and the mean of a subsample of the population. This source of error is strongly influenced by the size of the sample. The more samples in the subsample, the closer the mean would be to the whole population mean. Thus larger samples come closer to the true mean value for the indicator. They produce a lower standard error or standard deviation from the mean. The larger a sample, the easier it is to detect a difference between sample means drawn from separate populations. A good statistic describing this effect is the confidence interval. It represents the range of values within which there is 95 percent certainty that the true value for the whole population lies. The confidence interval is calculated as a range from the sample mean, based on the standard deviation and the standard normal distribution. It can be described as follows:

$$\mathbf{CI = \hat{Y} +/- Z_{\infty}(\sigma/\sqrt{N})}$$

Where:

CI = confidence interval

$\hat{Y}$ = the sample mean

Z_{∞} = the upper critical value of the standard normal distribution, which is found in the table of the standard normal distribution

σ = the standard deviation

N = the sample size

Note that as sample size increases, the confidence interval decreases. In other words, the interval is closer to the mean. There are two components in the confidence interval: the confidence interval width (distance from the mean) and the confidence level (e.g., 90 percent, 95 percent, etc.).

Using this statistic, a target sample size can be estimated by solving for N at a preselected confidence interval width and confidence level and using field data collected at the DMA of interest. This produces the following equation:

$$\mathbf{N = (Z_{\infty})^2(\sigma)^2/(\beta)^2}$$

Where:

β = the desired precision level expressed as half of the maximum acceptable confidence interval width

This equation is provided in the Data Entry Module, giving the user the option of estimating sample size adequacy while collecting data in the field. The default precision levels provided in the module are based on confidence interval widths from field tests for the indicators at a 90 to 95 percent confidence level.

Results using this equation for estimating adequate sample sizes are summarized for several test sites in table F6.

Note that sample size adequacy varies considerably by stream. These differences reflect the unique characteristics of diversity associated with each site and emphasize the need to evaluate sample size at each site and to adjust the minimum number of samples collected accordingly.

Some metrics do not fit a normal probability distribution as needed to apply the standard normal coefficient in the equations above. Streambank alteration, for example, is heavily skewed to the left at most sites. Samples usually contain no or just one alteration, with two or more alterations less common.

Electronic data entry may be used to assess sample size levels while collecting field data. The MIM protocol uses a Microsoft Excel workbook, the Data Entry Module, which is designed for use with PDAs and that allows computation of sample sizes for various levels of confidence using the equation above.

Table F6. Estimates of Sample Size Needed at the 90 Percent Confidence Level and Precision (β) at 10 Percent of the Mean

Stream	Streambank Alteration	Streambank Stability	Stubble Height	GGW	Woody Species Use	Substrate
Beaver Creek, South Dakota	67	72	23	69	47	311
Big Creek, Utah	79	83	56	23	na*	206
Darling Creek, Idaho	125	78	53	102	19	179
Ditch Creek, Idaho	135	81	51	61	15	242
Trout Creek, Oregon	69	45	62	68	47	245
Hardtrigger Creek, Idaho	47	53	29	99	11	384
Lawson Creek, Idaho	50	55	56	109	12	269
Long Tom Creek, Idaho	55	13	95	47	5	162
Blanchard Creek, Montana	15	22	60	91	19	74
Smart Creek, Montana	116	102	9	60	30	184
Telephone Creek, Idaho	31	39	22	59	81	346
Mill Creek, Oregon	38	5	28	21	14	149
Average	69	54	45	67	27	229
MAX	135	102	95	109	81	384
MIN	15	5	9	21	5	74

* na: not available–no woody plants present.

Using Precision to Evaluate Data and Detect Change: The ability to correctly evaluate data and detect change correctly is a critical step in the monitoring process. In natural stream and riparian systems, change is a relatively frequent natural process. The ability to isolate changes due to management requires that the method be robust, precise, and accurate and that some kind of reference to the disturbance events be available to calibrate changes due to natural disturbances.

A good way to detect changes in long-term indicators or to detect a failure to meet short-term indicators is to use a confidence interval around the mean that combines sources of variability or variations due to site complexity and revisit variance (observer plus within-season variation). Table F7 summarizes the statistics from all test sites for each metric indicator, including the combined 95 percent confidence interval.

The sample sizes, N, represent the number of stream reaches used in the replication analysis for a given indicator. The numeric indicators, stubble height, streambank

Table F7. Sample Size(N), Standard Deviation(SD), and 95 Percent Confidence Intervals (CI) for the Metric Indicators for All Repeat Sites

Metric	N	SD	CI
Average Stubble Height (in)	53	3.3	0.96
Streambank Alteration (%)	80	25.3	6.0
Woody Use (%)	52	5.7	5.2
Streambank Stability (%)	89	24.9	5.2
Streambank Cover (%)	89	21.8	4.5
Percent Seedlings + Young	66	29.7	7.2
Percent Mature	66	29.1	7.0
Hydric Plants (%)	89	22.2	4.6
Modified Winward Stability Rating (1-10)	89	0.8	0.16
Greenline Ecological Status (1-100)	89	27.7	5.75
Site Wetland Rating (1-100)	89	14.4	2.99
Greenline-to-Greenline Width (m)	109	0.3	0.3
Woody (%)	89	28.2	5.9
Hydric Herbaceous (%)	89	29.8	6.2
Percent Fines	9	17.8	11.6
Median Particle Size (mm)	9	41.2	26.9
Pool Frequency (pools per mile)	21	15.0	14.0
Residual Pool Depth (m)	21	0.23	0.06

alteration, greenline-to-greenline width, and woody use were analyzed using the statistics in table F4 and confidence intervals were derived from the mean for all reaches as shown at the bottom of that table. All other variables were analyzed from their reach summaries. For example, percent stable streambank is calculated from the total of all observations in a reach. The confidence interval for streambank stability was then determined from the sample size and standard deviation for all reaches.

The following examples demonstrate how to use table F6 in assessing short-term livestock grazing use indicators and in assessing change over time in a long-term condition indicator.

The streambank stability for a particular grazing unit has improved from 69 percent in 2007 to 80 percent in 2010. Is this a statistically valid increase? Using table F7, the confidence interval around the estimate is plus and minus 5.2 percent. Figure F1 displays this interval around the two estimates for 2007 and 2010. Because these two intervals do not overlap, we would conclude that the increase is likely to have occurred.

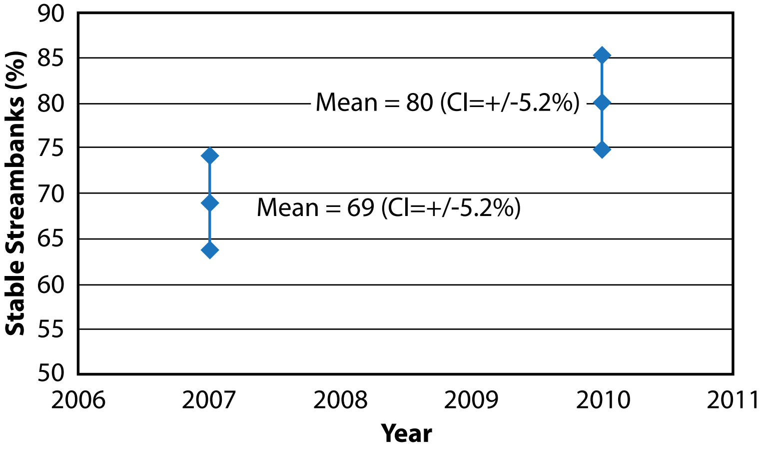

Figure F1. Detecting change through time using 95 percent confidence intervals (CI) from table F7. Change here would be significant given that both intervals do not overlap.

In the second scenario, the manager has establish the allowable streambank alteration level for the grazing allotment at 30 percent (this does NOT imply that 30 percent is an appropriate criterion anywhere else). At the end of the grazing season, streambank alteration is estimated to be 31 percent. Was the allowable use criterion exceeded? The confidence interval for streambank alteration in table F7 is 6 percent. Therefore the operation did not exceed the upper range for the criterion, or 36 percent. On the other hand, it may have begun to exceed the criterion at the lower end of the range or at 24 percent. It would be good for the manager to specify the range of confidence. One way to address variability is to make the lower end of the range the objective, and if it is reached, the operator then begins to move livestock off of the pasture. The upper end of the range could be used as a standard, which, if reached, might indicate a need to adjust the grazing practice.

Using reference sites, where the stream and riparian area are mostly absent of the management activity, is a good way to isolate management effects. This method assumes that both the DMA and the reference are concordant; that is, the indicator changes are in the same direction after a natural disturbance event.

An interesting example is the Big Elk Creek exclosure demonstration in north-central Idaho. Figure F2 displays the results of sampling the greenline-to-greenline width in each of two exclosures, one that has been fenced for 10 years and the other for 20 years. Widths for the unfenced, grazed pasture are also included in the figure for comparison to the exclosures. Confidence intervals around the mean, derived from table F7, are 0.3 meters.

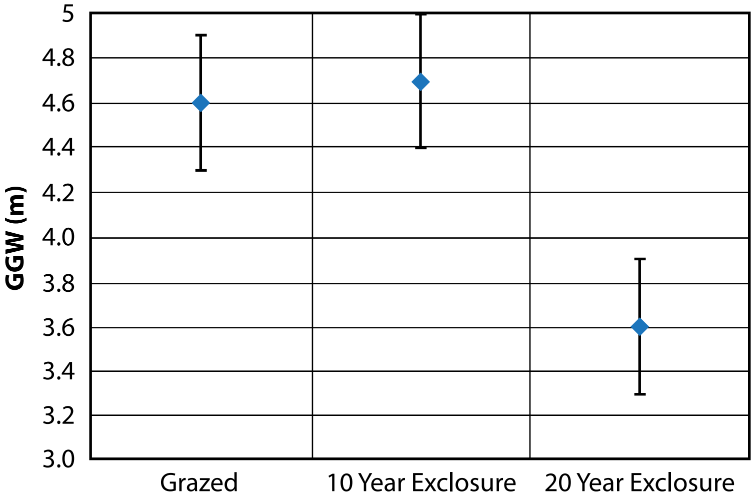

Figure F2. Using confidence intervals to define error bars around the average GGW for Big Elk Creek, Idaho.

The overlap between grazed and the 10-year exclosure on Big Elk Creek suggests that there is no significant difference between these two livestock use treatments. There is, however, no overlap between the 20-year exclosure and either the 10-year exclosure or grazed pastures. This suggests that after 20 years of rest, the GGW decreased significantly as vegetation encroachment and streambank stability increased on the channel margins. This kind of before-and-after controlled impact design has been used commonly in relation to exclosures (Sarr 2002), but previous approaches have relied upon some test, such as the t test for comparing two means. The current approach uses combined sources of measurement error as the means of testing differences.

In the absence of a reference site comparison, the observer should assess indicators of natural disturbance to inform potential effects beyond those caused by management. Climate records, streamflow data, and records of fire, grasshopper invasions, etc. would be helpful.

APPENDIX G: GREENLINE-TO-GREENLINE WIDTH (GGW) EXAMPLES*

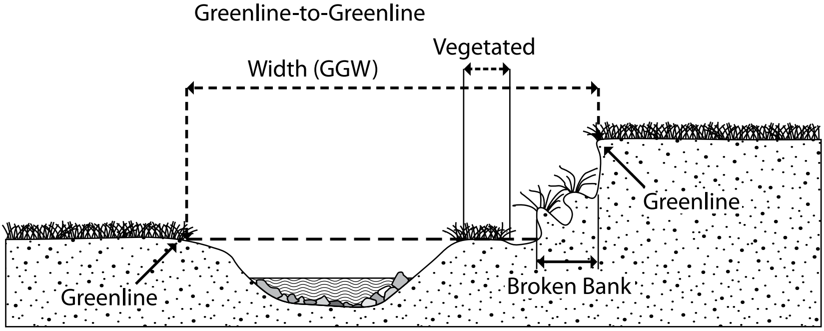

Figure G1. The greenline-to-greenline width (GGW) is the horizontal distance between the greenlines on each side of the stream measured perpendicularly to the flow of the stream. It is the nonvegetated stream channel. When vegetated (at least 25 percent foliar cover) slump blocks or islands are encountered along the line, the vegetated portion is subtracted from the total width and only the nonvegetated portion of the width is recorded.

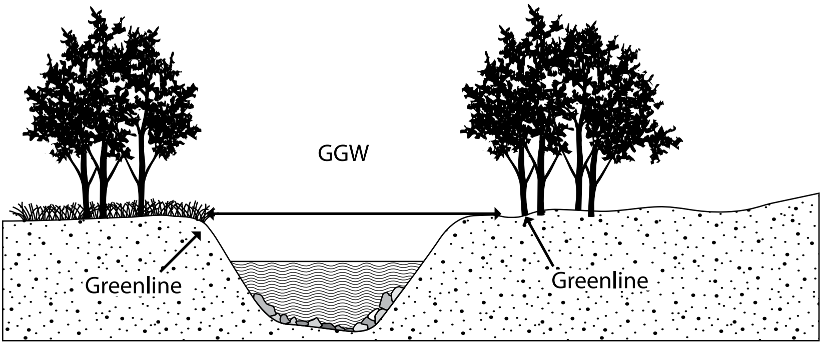

Figure G2. GGW is measured perpendicularly to the waterflow and from the rooted base on the greenline to the rooted base of plants on the greenline on the opposite side of the nonvegetated stream channel.

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* The dashed line shown in some figures represents the greenline.

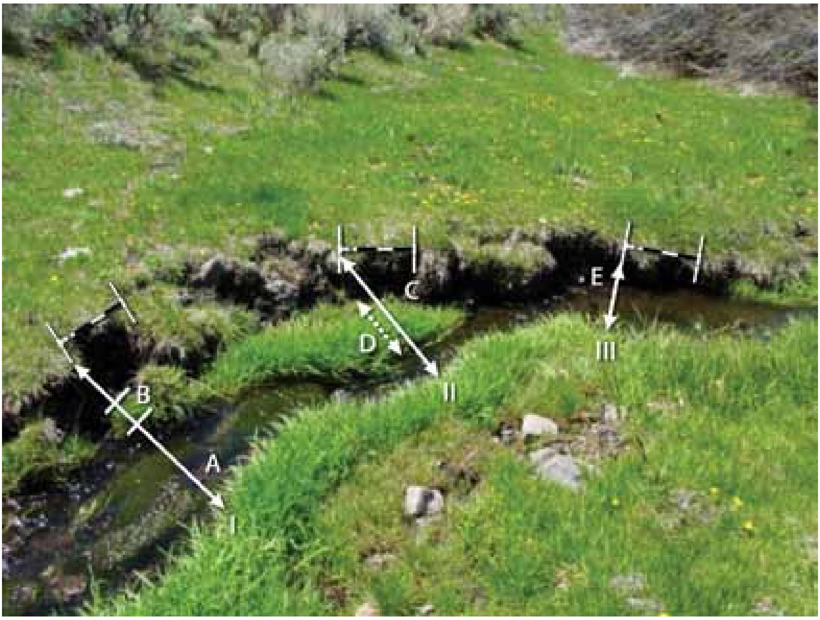

Figure G3. The GGW at location "I" is the length of line "A" minus the length of segment "B." The GGW at location "II" is the length of line "C" less the length of line "D." The GGW at location "III" is the length of line "E."

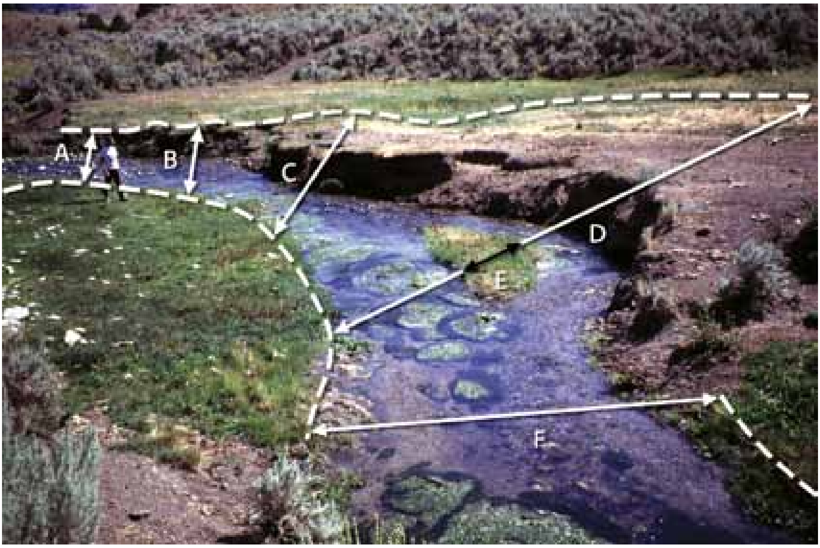

Figure G4. GGW is measured at regular intervals from one side of the stream at each plot location. Lines "A," "B," and "F" are the width of the nonvegetated stream channel measured perpendicularly to the waterflow direction. Line "C" shows a nonvegetated part above the steam. The GGW is measured between the greenlines. The GGW for line "D" is the total length of the line minus the distance on the island at "E."

Figure G5. Line "A" is the total length of the GGW. The gravel bar has no vegetation. When the GGW crosses an island with at least 25 percent cover, the nonvegetated portion is calculated (total length of line "B" – line "C") to determine the nonvegetated portion of the two channels. Photo - PIBO, U.S. Forest Service.

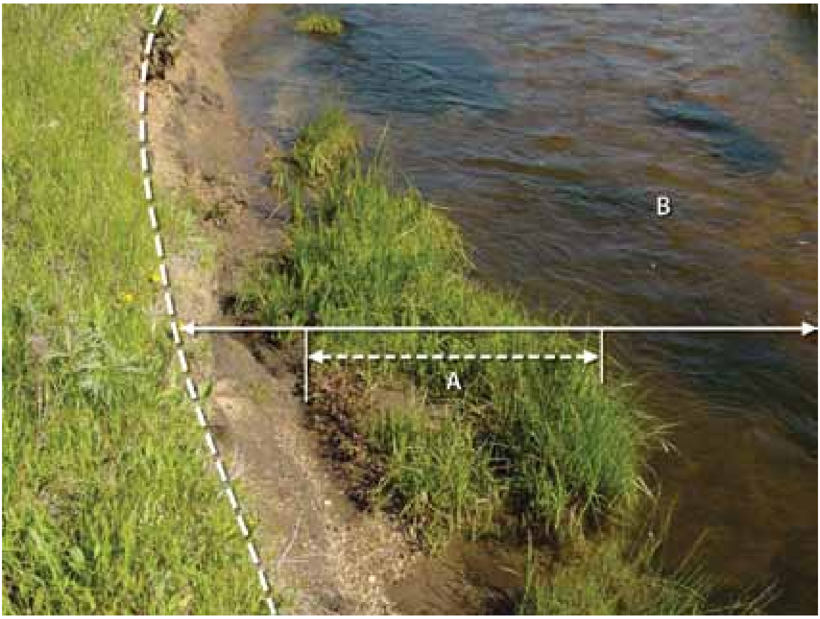

Figure G6. The slump block "A" is not attached to the streambank. The GGW is the total length of "B" less the width of the slump block.

APPENDIX H: PLANT LIST INFORMATION

The plant list contained in the Data Entry Module and the Data Analysis Module (see section V) was developed from multiple sources. The list is neither comprehensive nor complete. Users should update plant information and add plants for their areas when additional data are available or plants are not in the list.

Modified Winward Greenline Stability Rating

The literature is lacking in riparian and wetland plant species characteristics such as their extent of root systems and belowground biomass (Boyd and Svejcar 2009). The modified Winward (2000) greenline stability ratings provided in this document are mostly the professional opinion of various authors, including the authors of this document (see table H1). As data become available, users should update the information in the tables.

Ecological Status Rating

The ecological status rating for individual plants was determined from the sources listed in the references. Ecological status is sometimes referred to as “successional status, successional stage, or seral stage” and refers to the relative position of individual plants or a plant community in relationship to climax. This is related to the tendency of a plant to occur either earlier or later in a successional progression and is based on its relative shade tolerance and persistence. Since riparian areas associated with streams are dynamic, plants of all seral stages may be present in a late seral riparian community. Winward 2000 and USDA, Forest Service, no date, provided much of the information used to determine the successional status of plants.

The ecological status ratings for individual plants must be differentiated from the ecological status rating metric displayed for a site. The ecological status rating for a site is a summary metric that is calculated using individual ecological or successional status ratings and a weighted average of all plants recorded on the DMA according to their percent composition.

Many woody riparian species (most species of willow, cottonwood, alder, dogwood, and birch) require bare ground or freshly deposited sediment for seeds to germinate and establish (USDA, Forest Service no date). These plants also tend to live a long time (50 years or more). Even though they are early seral for establishment, they are long lived. Therefore, they are considered late seral for the MIM protocol.

Table H1. Modified Winward (2000) Greenline Stability Rating

Reference	Criteria	Modified Winward Greenline Stability Rating for Individual Plant Species
Winward 2000	**Winward Greenline Stability Rating**	
	1 to 3	Low (2)
	4 to 6	Medium (5)
	7 to 10	High (8.5)
Crowe and Clausnitzer 1997	**Streambank Erosion**	
	Poor = Low	Low (2)
	Fair = Moderate	Medium (5)
	Good = High	High (8.5)
	Excellent = High	High (8.5)
Authors' Criteria	**Modified Winward Greenline Stability Rating** - A relative value based on general rooting characteristics assigned by the authors or other referenced publications.	
	Forbs	
	Taproot and/or most roots, shallow (<15.2 cm)	Low (2)
	Fibrous roots, usually up to 30.5 cm	Medium (5)
	Rhizomatous roots, little indication of extensive fibrous roots	Medium (5)
	Rhizomatous roots, with extensive fibrous roots	High (8.5)
	Graminoids	
	Annual, biennial, and short-lived perennials	Low (2)
	Stoloniferous, caespitose, tufted, or short slender rhizomatous perennials (<1 m tall)	Low (2)
	Slender or thin creeping rhizomes	Medium (5)
	Long, stout, well-developed creeping rhizomes	High (8.5)
	Woody Species	
	Taprooted species	Low (2)
	Short shrubs (<1 m tall) with shallow root systems	Low (2)
	Shallow to moderate root systems	Medium (5)
	Rhizomatous root system, generally shallow (<31 cm)	Medium (5)
	Root crown with spreading roots	High (8.5)
	Widespread root systems	High (8.5)

The ecological status rating classes for individual plants are:

Early Seral (E) – All annual and short-lived (living less than 5 years) perennial plants tend to be replaced by plants that live longer. All noxious weeds and shallow-rooted perennial species that tend to be tolerant of grazing and other uses are classified as early seral.

Mid-Seral (M) – Perennial plants, mostly forbs that are not shade tolerant and tend to have fibrous root systems. These plants are usually replaced in a riparian community by long-lived plants.

Late Seral (L) – Plants that usually exist in the most stable riparian plant communities. They tend to stabilize streambanks and develop extensive root systems.

Wetland Status

The "1996 National List of Vascular Plant Species that Occur in Wetlands" (U.S. Army Corp of Engineers 1996) was used to establish the wetland rating.

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GLOSSARY

Available woody species: The height to which large herbivores, e.g., cattle, sheep, horses, deer, elk, and moose, can graze on woody plant species. The taller the animal, the higher they can browse.

Bankfull stage (or level): The elevation of the bank where flooding begins. The bankfull level is associated with the streamflow that just fills the channel to the top of its banks where water begins to overflow onto the floodplain. This streamflow level is often associated with moving sediment, bar formation, and, generally, the work that forms the morphological characteristics of the stream channel (Wolman and Miller 1960).

Bench: A relatively flat area, more or less parallel to the stream, which may be a floodplain or terrace.

Current year's leader or twig growth: That portion of the stems of woody plants that reflects the current year's growth or that extends from the terminal buds of 2-year-old growth. Leaders represent the dominant trunk of a branch or stem; twigs represent the terminal parts of the branch or stem.

Designated monitoring area (DMA): A DMA, for the purposes of this protocol, is a permanently marked segment of stream that has been selected for monitoring. It refers to the specific sampling location that extends at least 110 m along the stream. Longer segments may be needed for monitoring larger streams (over 5.5 m greenline-to greenline width or GGW). For such streams, the DMA should be at least two meander wavelengths or approximately 20 times the GGW (Gordon et al. 2004). For example, a DMA on a stream segment with an average GGW of 8.3 m would be 8.3 m x 20, or 166 m in length.

False bank: A slump block that is reattached to the streambank creating a new floodplain.

Fines: Substrate particles that are less than 6 mm in diameter.

Floodplain: The relatively flat area adjacent to a stream or lake that experiences occasional or periodic flooding. Dunne and Leopold (1978) defined the floodplain as the flat area adjoining a river channel constructed by the river in the present climate and overflowed at times of high discharge.

Foliar cover: The amount of live plant parts, leaves, twigs, stems, and branches that covers the ground surface expressed as a percentage. Foliar cover is the shadow cast if the sun was directly overhead.

Geomorphology: The study of landforms and the processes that form them.

Greenline: A linear grouping of perennial plants at or near the water's edge along a stream channel.

Greenline-to-greenline width (GGW): The nonvegetated width of a stream channel measured from the greenline on one side of the channel perpendicular to the streamflow to the greenline on the opposite side.

Hoof shearing: A broken part of the streambank caused by the weight of a hoof or foot stepping on the streambank and causing it to break down. Shearing is usually the most obvious form of streambank disturbance caused by animals.

Island: Areas surrounded by water or bounded by a channel that is scoured frequently enough to keep perennial vegetation from growing at summer low flow.

Key species: Those plant species that are important (relatively common and desirable) in the plant community, are relatively palatable to livestock, and serve as indicators of change.

Obvious streambank alterations: Those alterations to the streambank that are easily seen, clear to the eye, not to be doubted, or plain (Thorndike and Barnhart 1993).

Pool: A depression or deeper part of a stream channel that usually has slower moving water.

Riffle: A part of a stream that is locally steeper and shallower than adjacent reaches and has fast, shallow water causing choppiness on the water surface.

Riffle crest: The point at the lower end of a pool where water flows to a riffle.

Riparian complex: The overall geomorphology, substrate characteristics, stream gradient, and vegetation patterns along the stream.

Scour line: The elevation of the ceiling of undercut banks at or slightly above the summer low-flow elevation or, on depositional banks, the lower limit of sod-forming or perennial vegetation.

Slump block: A block streambank that has completely detached and is within the stream channel.

Stratification: Dividing the length of a stream using specific criteria resulting in stream segments with similar characteristics.

Streambank alteration: Streambank disturbance caused by animals (e.g., elk, moose, deer, cattle, sheep, goats, and horses) walking along the streambanks or the margins of the stream. The animals' weight can cause shearing that results in a breakdown of the streambank and subsequent widening of the stream channel. Streambank alteration also exposes bare soil, increasing the risk of erosion of the streambank. Animals walking in the channel margins may increase the amount of soil exposed to the erosive effects of water by breaking or cutting through the vegetation and exposing roots and/or soil. Excessive trampling causes soil compaction, resulting in decreased vegetative cover, less vigorous root systems, and more exposure of the soil surface to erosion.

Stream gradient: The gradient is the slope or amount of vertical drop along the stream channel per unit horizontal distance. It is usually expressed as a percentage.

Terrace: A level surface flanking, and more or less parallel to, a stream channel located upslope of the active floodplain. A terrace represents an abandoned floodplain that is not flooded, except possibly on rare occasions associated with extremely large floods.

Thalweg: A line joining the lowest points along the length of a streambed in its downward slope, defining its deepest channel.

Trampling: Animal-caused depressions in the soil surface or soil compaction along the streambank or crossing the channel.

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