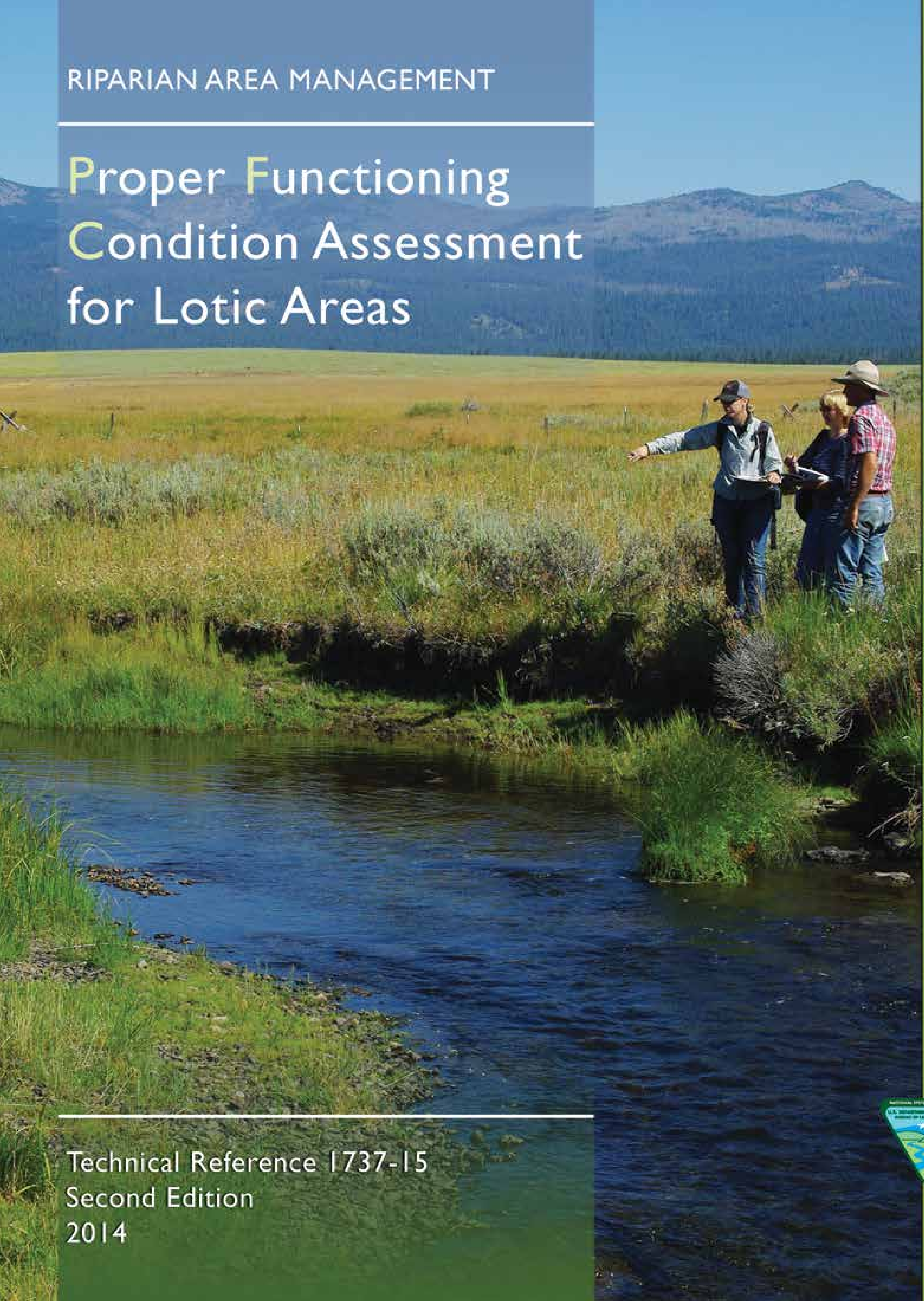
RIPARIAN AREA MANAGEMENT

Proper Functioning Condition Assessment for Lotic Areas



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Abbreviations

BLM – Bureau of Land Management

DMA – Designated monitoring area

FAR – Functional–at risk

GIS – Geographic information system

ID – Interdisciplinary

MIM – Multiple indicator monitoring

NF – Nonfunctional

NRCS – Natural Resources Conservation Service

PFC – Proper functioning condition

PNC – Potential natural condition

TR – Technical reference

USGS – U.S. Geological Survey

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1. Introduction

A riparian area is the transition between the aquatic area and adjacent upland areas (see example in figure 1). These areas exhibit vegetation or physical characteristics reflective of permanent surface- or subsurface-water influence. Though there is not a single, consistently used definition for riparian areas, this description includes qualities common in many current definitions (National Academy of Sciences 2002).

Riparian areas are complex, dynamic ecosystems incorporating biological, physical, and chemical processes. The proper functioning condition (PFC) assessment method was created to qualitatively evaluate the foundation of these processes—specifically the functionality of the physical processes occurring on a stream. These physical processes include the interactions of hydrology, stabilizing vegetation, and geomorphology (soils and landform). A quality assessment requires that an interdisciplinary (ID) team with expertise in these subjects assess the stream together. Because the PFC assessment compares each stream to its own potential, it is universally applicable to all but the most highly modified perennial and intermittent streams.

The abbreviation PFC describes both the assessment method and a defined, on-the-ground condition of a riparian area. The on-the-ground condition termed PFC refers to how well physical processes are functioning. A system in PFC has a high likelihood of withstanding a moderately high flow event (such as the 5-, 10- or 25-year flow). If impairment does occur with higher magnitude events, a system in PFC can recover more quickly.

The PFC assessment method refers to a consistent approach for considering hydrologic, vegetative, and geomorphic attributes and processes to assess the condition of riparian

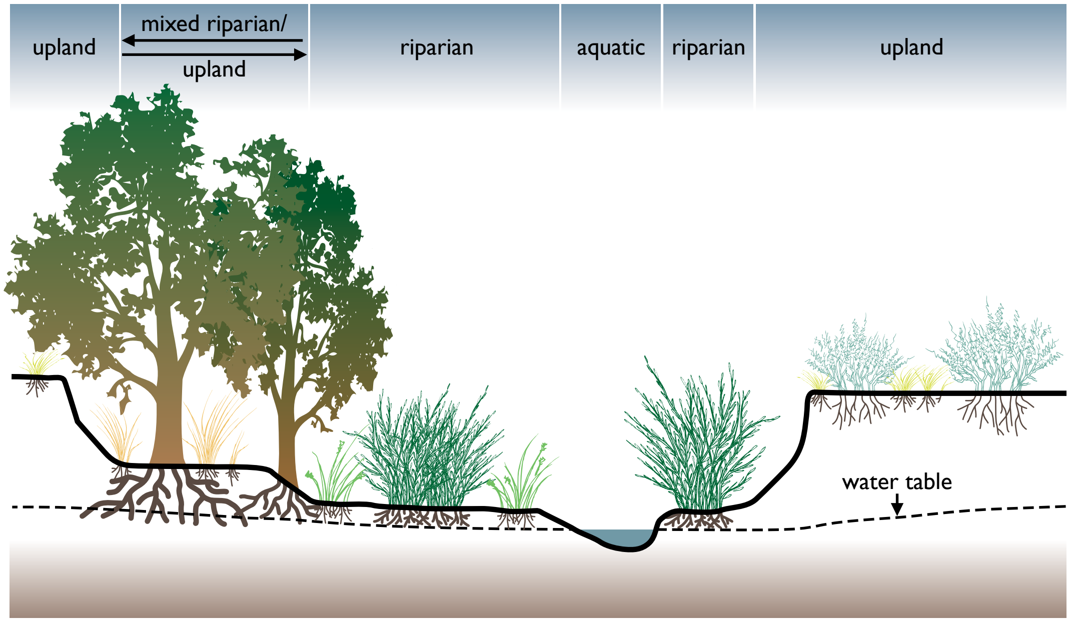


Figure 1. A riparian area is the transition from the aquatic area to the upland area. Vegetation is expected to change from species adapted to wetter sites near the channel to species adapted to drier sites in the upland, with a mixture of species occurring in between. In this example, an assessment of riparian function would consider the riparian areas, mixed riparian/upland areas, and active channel in the reach. Not all riparian areas have all of these features.

areas at a point in time. Information pertaining to 17 attributes and processes of a riparian system is foundational to determining its physical function and is synthesized on an assessment form (appendix A). Based on the responses and comments on the assessment form, the stream reach is placed in one of three rating categories:

Proper functioning condition (PFC): A lotic riparian area is considered to be in PFC, or "functioning properly," when adequate vegetation, landform, or woody material is present to:

- Dissipate stream energy associated with high waterflow, thereby reducing erosion and improving water quality.
- Capture sediment and aid floodplain development.
- Improve floodwater retention and ground-water recharge.
- Develop root masses that stabilize streambanks against erosion.
- Maintain channel characteristics.

A riparian area in PFC will, in turn, provide associated values, such as wildlife habitat or recreation opportunities.

Functional–at risk (FAR): These riparian areas are in limited functioning condition; however, an existing water, vegetation, or landform attribute makes them susceptible to impairment.

Nonfunctional (NF): These riparian areas clearly are not providing adequate vegetation, landform, or woody material to dissipate stream energy associated with moderately high flows, and thus are not reducing erosion, improving water quality, etc.

The minimum acceptable management goal for a riparian area is at least PFC because any rating below PFC indicates a condition that is not sustainable. If a riparian area is functioning properly, then processes are in place to create and maintain values associated with the potential of the reach, such as quality habitat and clean water. If, on the other hand, the riparian area is not functioning properly, it is likely that these values will be impaired (Harman et al. 2012; Shields et al. 2010). However, attaining PFC does not necessarily mean that chemical and biological processes are unaffected. For example, sediment, thermal, or nutrient regimes could remain impaired because of upstream impacts that are transmitted downstream. Protocols that assess or monitor chemical or biological functions can be used to understand these parameters in conjunction with the PFC assessment.

An ID team must understand stream dynamics and potential and use their professional experience and judgment to accurately complete a quality assessment. Although a PFC assessment relies on basic concepts of stream function, it cannot be completed by personnel who lack specific subject-matter training, relevant experience, or firsthand knowledge of local riparian systems. It requires thoughtful observation of various stream conditions in various states and a background in quantitative measurements. A PFC assessment involves both the art and the science of "reading the landscape" and developing a working understanding of each requires time and experience.

Purpose of This Technical Reference and Changes from Earlier Editions

This technical reference (TR) provides instructions for the application of the PFC protocol. It is not intended to serve as a textbook addressing every aspect of stream and riparian function and ecology. The PFC protocol addresses the physical functioning of perennial or intermittent lotic (flowing water) riparian systems, such as rivers or streams. Lentic (still or very slow-moving water) riparian systems, such as wetlands, ponds, or marshes, are addressed in a separate TR (Prichard et al. 2003). The PFC assessment protocol is not intended for use on ephemeral systems, which do not support the vegetation, riparian functions, and values that are dependent on extended periods of streamflow and availability of free water in the soil.

The PFC method is a qualitative assessment based on quantitative science. For example, item 17 on the PFC assessment form asks whether the stream is in balance with the water and sediment being supplied by the watershed. An out-of-balance system would lead to excessive deposition or erosion. Excess sedimentation forming mid-channel bars where they would not be expected or bank erosion at areas other than outside meander bends of the stream provides visual evidence without needing detailed measurements to judge whether this is happening. If compelling visual evidence is absent or if the channel dimensions need to be quantified or tracked over time, other monitoring tools provide the rigorous methods to do so. The same kind of scenario can be produced for each assessment item.

Use of quantitative techniques is encouraged in conjunction with the PFC assessment for individual or ID team calibration or where opinions differ among specialists. PFC is also an appropriate starting point for determining and prioritizing the type and location of quantitative inventory or monitoring needed, and it can provide context for quantitative data. Appendix B provides a list of possible quantitative techniques for stream assessment.

The PFC method was first presented in TR 1737-9, "Process for Assessing Proper Functioning Condition" (Prichard et al. 1993). In 1998, TR 1737-9 was updated to include more detail on how to apply the PFC protocol. This revision, TR 1737-15, was entitled "A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas" (Prichard et al. 1998) and incorporated input from resource specialists in the Bureau of Land Management (BLM), Forest Service, Natural Resources Conservation Service (NRCS), and state riparian teams in the Creeks and Communities Network. Since that revision, the PFC method has been further implemented by the BLM and several other agencies and has been widely used on numerous stream systems in the United States. This widespread application of the tool has helped practitioners identify several needed updates and improvements.

This second edition of TR 1737-15 does not alter the overall approach from the 1998 document. The majority of the changes address the need to include new science, provide better examples, clarify the wording of some of the assessment items and sections, and provide additional detail where needed. Because a number of new quantitative procedures have been developed since 1998, the quantitative procedures available to validate PFC assessments have been updated. This edition includes examples to describe how PFC fits into an overall integrated riparian management process and to emphasize the work required before and after conducting a field assessment of a reach.

The process for applying potential and capability to the PFC assessment has been refined to improve the consistent use of these concepts. Potential is described in detail, and the specific term "capability," used in the 1998 version to describe limiting factors as a result of human changes, is no longer used. The concept for addressing the same limiting factors in a unique way still applies; however, the term "altered potential" (a more direct term) is now used, and a set of guidelines has been developed to help users evaluate how human alterations affect potential.

The first edition of this document provided citations each time a Rosgen stream type (Rosgen 1996) was referenced. Although many different classification systems are available and each one brings valuable information to a discussion of stream condition, in this edition, stream types will be described using the Rosgen stream classification system without additional reference. This system is widely used and provides a good "common language" to communicate information about channel morphology. See appendix C for a key to the Rosgen classification of natural rivers (Rosgen 1997).

In addition, the order of items 6 and 7 has been reversed on the assessment form from previous versions to create a more logical flow to the assessment process. This reversal will need to be considered in database management.

Intended Applications

The PFC assessment protocol **is** designed to:

- **Assess the function of perennial and intermittent streams and their associated riparian areas.** The attributes and processes developed for the PFC assessment are specific to perennial and intermittent streams. Other protocols could be used or developed to assess ephemeral systems (e.g., Pellant et al. 2005).
- **Be used on most stream and river systems, regardless of size.** Because each riparian area is assessed against its own specific potential, the PFC protocol can essentially be used on any size lotic system provided that the ID team fully understands the attributes and processes influencing the function of that system. For example, in 2010, a PFC assessment was successfully completed on the Upper Missouri River, a large river in Montana.
- **Be used only by an experienced ID team of resource specialists.** Because PFC is a qualitative assessment of indicators of stream and riparian function, most resource specialists completing the PFC assessment should have a strong technical background and experience collecting, analyzing, and interpreting quantitative data related to the assessment items specific to their discipline. Also, most ID team members should have local experience in the watershed(s) being assessed. The PFC assessment provides a good communication tool to discuss stream functions with stakeholders; however, on federal lands, the agency ID team is responsible for answering evaluation items and determining final ratings.

- **Provide a consistent approach for assessing the physical functioning of riparian areas** through consideration of hydrologic, vegetative, and geomorphic attributes relative to the potential of the stream being assessed. The PFC assessment synthesizes information that is foundational to determining the overall health of a riparian area.

- **Help establish and prioritize management, monitoring, and restoration activities.** The PFC assessment can provide an early warning of problems and point to opportunities by helping to identify key management issues, focus monitoring activities to maximize efficiency, and prioritize restoration actions on the "at-risk" systems or reaches of highest resource value.

- **Provide a focused and effective foundation for determining resource values and developing management goals** by identifying attributes and processes that are out of balance for the landscape setting.

- **Communicate fundamental riparian concepts** to a wide variety of audiences. This process forms a "common vocabulary" for discussing physical stream and riparian functions as the basis for developing common understanding and vision for long-term desired conditions.

The PFC assessment protocol **is not** designed to:

- **Assess the function of ephemeral systems.**

- **Be used by inexperienced personnel.** Because PFC is an observational assessment, personnel must have enough experience to recognize and interpret visual indicators of function.

- **Be completed *without* an ID team.** While individuals may learn about riparian areas by incorporating the PFC thought process, the assessment must be completed by an ID team.

- **Monitor resource conditions and trends.** PFC is an assessment and is not intended to be a monitoring tool because it generally lacks the sensitivity to detect incremental changes in riparian condition.

- **Assess specific resource values or be the sole method for assessing the health of the aquatic or terrestrial components of a riparian area.** The PFC assessment is not a replacement for inventory, assessment, or monitoring protocols designed to yield information on the "biology" of the plants and animals or other habitat parameters. PFC is not synonymous with potential natural condition, but is generally a prerequisite for achieving and maintaining habitat quality and other values.

- **Assess the function of streams where human alterations have created artificial channel conditions for a substantial part of the reach.** Instructions for how to consider altered stream reaches are included in chapter 4.

2. Managing Riparian Areas Using an Integrated Process

A PFC assessment can be incorporated into an integrated riparian management process through a logical sequence of actions (figure 2).

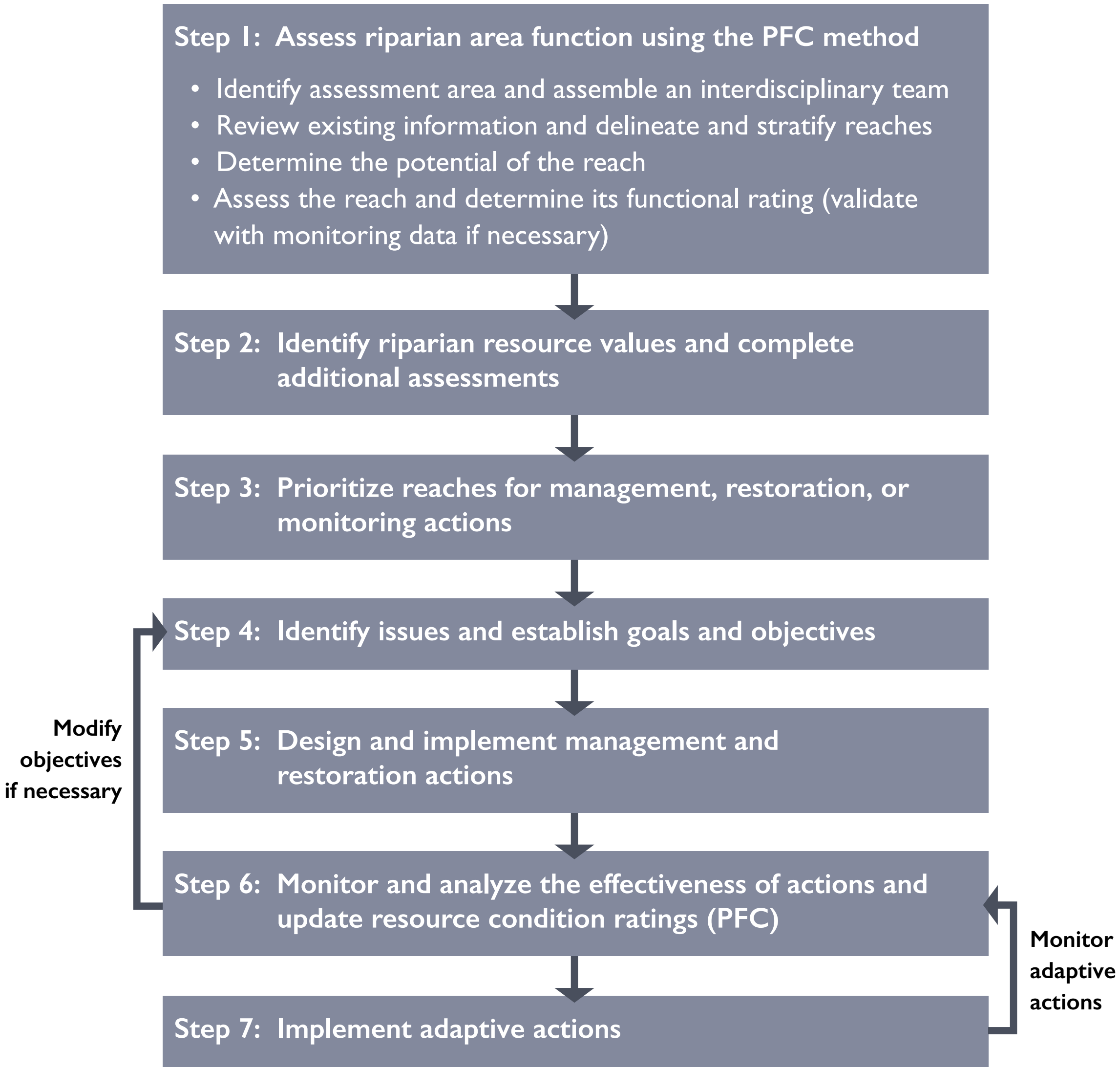
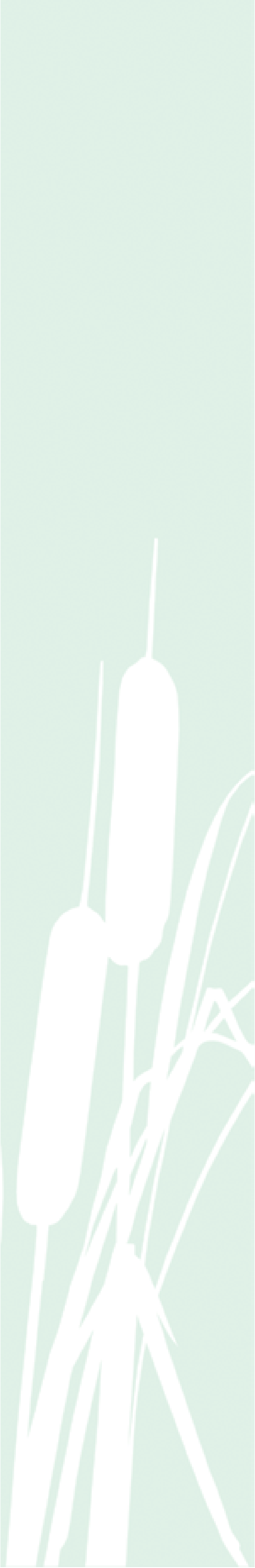


Figure 2. Recommended steps for managing riparian areas using an integrated process. After effectiveness monitoring has been done (step 6), initial objectives are validated and modified if necessary. After implementing adaptive actions, step 6 is repeated to monitor the effectiveness of those actions.



Step 1: Assess Riparian Area Function Using the PFC Method

Completing a PFC assessment is an effective way to initiate a comprehensive and integrated riparian management process because it provides fundamental information for subsequent management, restoration, or monitoring actions. The focus of chapters 3 through 8 is to provide detailed instructions for conducting a PFC assessment, which consists of the following tasks:

- Identify the assessment area and assemble an ID team.
- Review existing information and delineate and stratify reaches.
- Determine the potential of the reach.
- Assess the reach and determine its functional rating (validate with monitoring data if necessary).

Step 2: Identify Riparian Resource Values and Complete Additional Assessments

Within the assessment area, identify resource values (which include habitat values) for the various reaches that will later be used to help establish priorities for management, restoration, and monitoring. Values include fish and wildlife habitat, recreational opportunities, livestock forage, sensitive plants, water quality, Endangered Species Act requirements, species of concern, special interest areas, etc. Although resource values are usually established at some level in a land use plan, values should generally be validated or refined at the reach scale.

Once values are identified, they may require additional assessment. A PFC assessment provides fundamental information regarding the physical function and condition of the riparian area; however, additional information is often needed to obtain a comprehensive assessment of riparian condition. Fish or wildlife habitat and water quality assessments are examples of additional resource assessments that may be needed to characterize overall riparian condition in preparation for subsequent activities. Often these assessments can be done simultaneously with the PFC assessment.

Step 3: Prioritize Reaches for Management, Restoration, or Monitoring Actions

Once resource values are identified, those values, along with the PFC assessment results, provide a basis for prioritizing reaches for management, restoration, or monitoring actions.

Although restoring function is a fundamental priority, some stream reaches at PFC may not be meeting other habitat or desired condition objectives and may also be a high priority for management, restoration, or monitoring due to legal mandates or other needs. These needs are factored into the prioritization process along with NF and FAR reaches and their corresponding values.

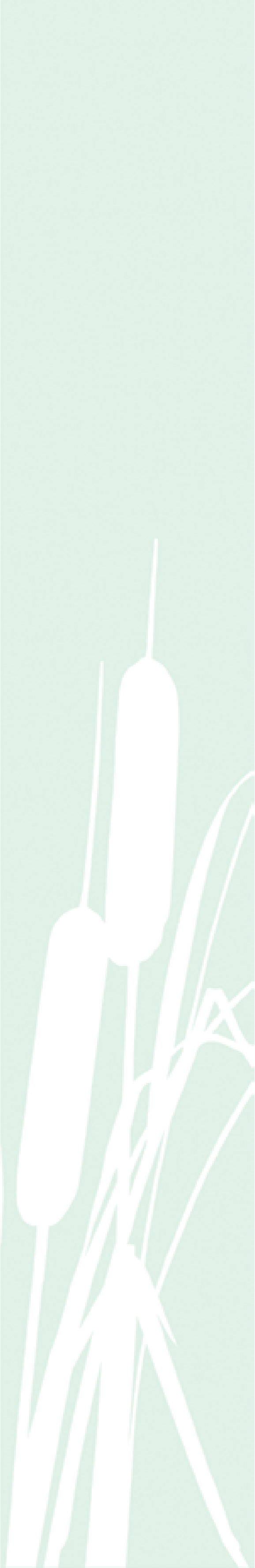
By concentrating on the sensitive at-risk areas that may be near the threshold of rapidly degrading into nonfunctional condition, timely management changes or restoration activities can halt the decline and begin the recovery process before deterioration progresses further and recovery actions become expensive. Often, once an area is nonfunctional, the effort, risk, cost, and time required for recovery dramatically increase. There are also instances where neither management nor restoration actions are necessary, but the area is a high priority for monitoring due to a need to document condition or track changes (trend).

Restoration of most nonfunctional systems should be reserved for those situations in which the riparian area has reached a point where recovery is possible, efforts are not at the expense of at-risk systems, or unique opportunities exist. Nonfunctional systems should not be ignored but may take a lot of money to restore function; natural evolution may be the best course of action for these systems. At the same time, areas that are functioning properly are often not the highest priorities for additional restoration work towards potential because they are more resilient than the at-risk areas. However, it is critical to manage these areas to retain their resilience and further progress towards desired condition.

Because not all at-risk reaches have the same resource values, information from the PFC assessment should be combined with reach-specific resource values to establish reasonable priorities. Reaches that are FAR with high resource values would be a higher priority than FAR reaches with low resource values.

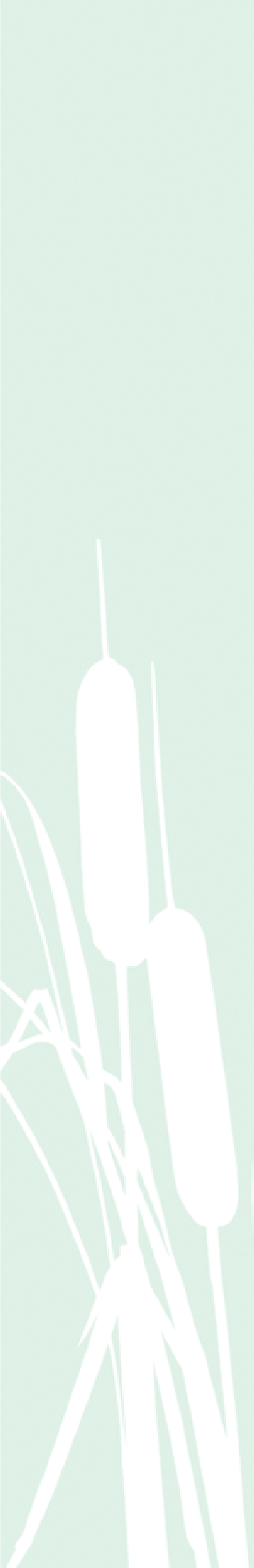
The PFC assessment can also help determine the appropriate timing and focus for riparian restoration projects (including structural and management changes). It can identify situations where instream structures are either entirely inappropriate or premature.

The results of the PFC assessment can be used to identify watershed-scale problems and suggest management remedies and priorities. Whereas the methods and data are reach based, the ratings can be aggregated and analyzed at the watershed scale. Information from the PFC assessment, along with other watershed and habitat condition information, helps provide a good picture of the watershed and the possible causal factors affecting watershed health.



Step 4: Identify Issues and Establish Goals and Objectives

The completed PFC assessment, combined with additional resource assessments, not only provides comprehensive information about both physical function and attendant resource values, it also highlights specific resource issues (by reach) that need to be addressed. Because PFC is a broad-scale, systematic reconnaissance, it is very effective in identifying issues that may have been missed during sporadic field inspections. For example, the PFC assessment may reveal that although vegetative cover along a reach is high, the cover of stabilizing species is low. This situation is preventing the reach from achieving PFC and desired habitat values.



The information obtained from the PFC assessment can be used to develop goals, such as increasing the cover of stabilizing species. The ID team should describe goals that are tied to the findings of the PFC assessment (and other assessment or monitoring information) that can be refined later if quantitative data are collected.

Information from the PFC assessment will allow the ID team to focus on key attributes (e.g., stabilizing vegetation) that need to improve and subsequently be monitored to determine if improvement has occurred. Low-priority reaches may only require the creation of broad goals, and thus, often need only infrequent qualitative monitoring, while other reaches may need specific, quantitative objectives and subsequent quantitative monitoring. Baseline data are usually necessary to establish quantifiable resource objectives for reaches identified during the PFC assessment. The term “baseline data” refers to the initial collection of data, which serves as a basis for comparison with the subsequently acquired data. Some baseline data may already have been collected for reaches where validation monitoring was done to support the PFC assessment.

Good objectives should be based on the potential of the stream reach and should include components illustrated by the acronym “SMART” (Adamcik et al. 2004):

1. **S**pecific
2. **M**easurable
3. **A**chievable
4. **R**esults-oriented
5. **T**ime-fixed

Writing effective quantitative objectives involves determining the current state of an attribute, how much it may need to change, and the timeframe necessary to achieve it. Other quantitative techniques can be used as appropriate to collect baseline resource and habitat data as well (see appendix B for additional techniques tied to the PFC assessment). If, for example, stabilizing plant species are found to be lacking along a reach and streambanks are unstable, an example of a goal would be to improve streambank stability, and one related “SMART” objective would be to improve streambank stability from the current 65 percent to 85 percent in 5 years on Willow Creek at monitoring area WC#12.

Most stream reaches will have a short list of multiple objectives. Although the example objective described above is more tied to functionality, other resource objectives should be included on this list as well (one example would be percent fine sediment). It is sometimes advantageous to establish intermediate objectives (3-7 years) and long-term objectives (>7 years) for streams that need considerable time to recover. Progress towards management objectives is partly a function of management actions and partly controlled by environmental circumstances such as the timing of floods, droughts, fire, and other watershed disturbances. Objectives may need to be modified as part of the adaptive management process; as a result, this step is part of the iterative process to accommodate the modification of objectives if necessary.

Step 5: Design and Implement Management and Restoration Actions

Once the preceding steps have been completed, management and restoration actions can be designed and effectively set in motion. Management and restoration actions for selected reaches, sites, or units within the assessment area (e.g., grazing allotment) are planned and implemented specifically to address established objectives.

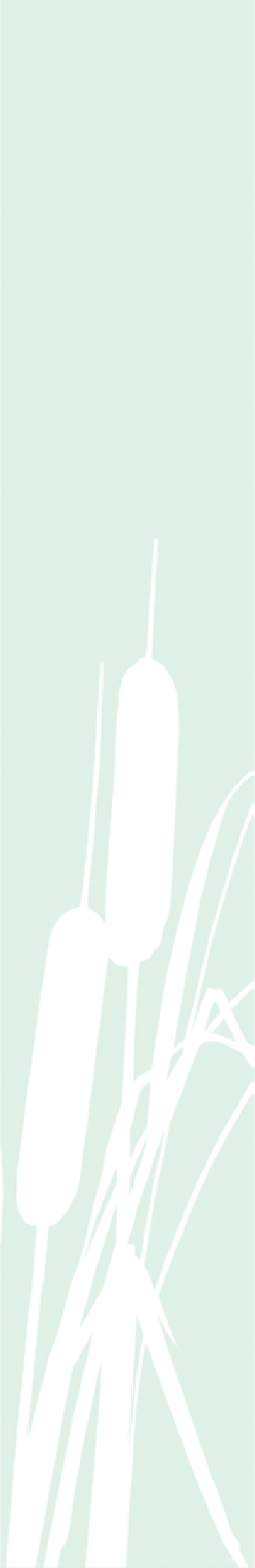
Step 6: Monitor and Analyze the Effectiveness of Actions and Update Resource Condition Ratings (PFC)

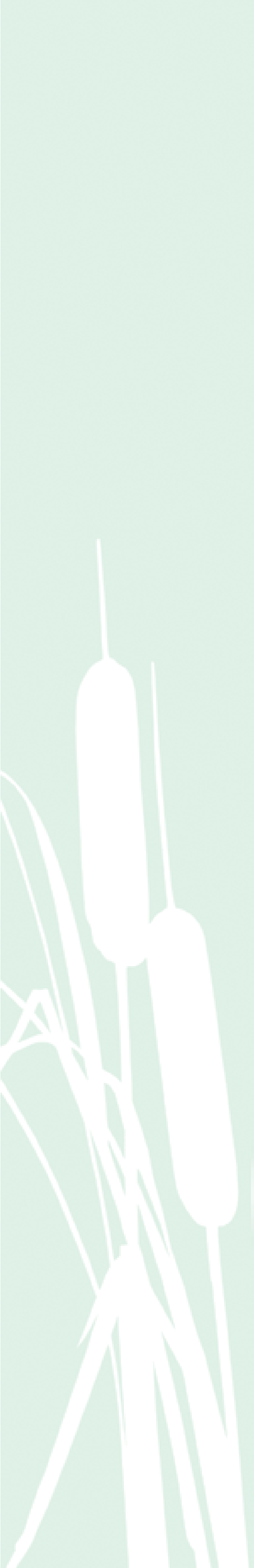
Two types of monitoring are commonly done for land management purposes: (1) implementation monitoring, and (2) effectiveness monitoring. Implementation monitoring is often referred to as short-term monitoring and is necessary to evaluate whether a management action was implemented properly. To document actions and to help establish cause and effect relationships when evaluating trend, some level of implementation monitoring should be done periodically for ongoing activities such as grazing by livestock or wildlife. Monitoring the results of management or restoration actions is effectiveness monitoring. Effectiveness monitoring is often referred to as long-term monitoring and is necessary to evaluate trend or progress towards the achievement of objectives and to determine if key attributes and processes evaluated during the PFC assessment have changed. The most appropriate way to monitor the effectiveness of actions is to reread the baseline data that was collected using the same techniques. Long-term effectiveness monitoring should generally be completed at intervals appropriate to evaluate the achievement of objectives (3-7 years).

For grazed areas, the multiple indicator monitoring (MIM) protocol (Burton et al. 2011) provides techniques for short-term (annual) implementation monitoring of stubble height, streambank alteration, and woody species use along the streambank. It also provides methods for measuring seven long-term effectiveness indicators along the stream channel, streambank, and streamside that are useful for developing and monitoring the achievement of objectives.

Quantitative monitoring should take place at formal designated monitoring areas (DMAs). DMAs are permanently marked segments of streams that serve as the locations where monitoring data are collected for developing and tracking the achievement of riparian objectives. The MIM protocol (Burton et al. 2011) describes a process and criteria for establishing DMAs. Elzinga et al. (1998) also provided detailed information for sampling design and quantitative monitoring. Often DMAs are selected to represent FAR reaches where the PFC assessment identified a need for a management change or a monitoring focus.

Burton et al. (2011) state, “It is important that DMAs are established by an ID team of highly experienced personnel with knowledge of the management area.” Because an experienced ID team has been assembled to do the PFC assessment, which involves delineation and stratification of reaches/complexes, an appropriate time to locate new DMAs or validate the location of existing DMAs is either during or immediately following a PFC assessment.





Representative DMAs are established to represent larger areas and should be based on priority actions (identified from the PFC assessment and an analysis of resource values) for which monitoring will be used in adaptive management. How much an attribute can be expected to change should be based on a reasonable estimate of the potential of the reach. Measurements at a reference DMA can be an effective way to establish quantitative objectives for the representative DMA.

Monitoring may indicate a need to update resource condition ratings. PFC assessment ratings commonly need to be updated for various purposes (such as for completing a National Environmental Policy Act analysis). For example, if a stream reach was rated less than PFC during the initial assessment and a management change was implemented, the assessment will eventually need to be updated. Because PFC is not a monitoring tool, repeating a complete PFC assessment to detect improvement (or deterioration) is usually not necessary or particularly useful in most cases. PFC is a coarse assessment tool that is not precise enough to detect small changes in condition.

If the management steps presented in this chapter are used, some level of monitoring (qualitative or quantitative) will have been done if a DMA has been established on the reach. An ID team can use monitoring data to help update a PFC assessment because most of the assessment items are quantifiable. However, not all assessment items can be quantified (e.g., stability of beaver dams, plant vigor), and some of the quantifiable assessment items may not have any data associated with them at the time of the PFC update. To update the PFC assessment, the ID team will use the available quantitative data as appropriate and assess items that were not quantified (using remote sensing and field reconnaissance) to analyze any change in condition for those items. As with the original assessment, interpreting monitoring data and updating the PFC assessment in this manner must be done by an experienced ID team.

Reassessing a reach using the comprehensive PFC protocol is necessary in some circumstances, such as where dramatic ecological disturbances such as a fire or flood have considerably changed the reach. Also, if considerable time has elapsed since the initial assessment or if the quality of the original PFC assessment is suspect, the ID team may determine that a comprehensive PFC assessment needs to be repeated.

The following example illustrates an effective way to update the status of PFC assessments where quantitative monitoring has been done:

1. The reach was rated FAR primarily due to a lack of adequate stabilizing riparian vegetative cover on streambanks.
2. Baseline data collected shortly after the PFC assessment revealed that streambank stability was 65 percent and the streambank lacked stabilizing riparian plants.
3. Effectiveness monitoring was completed on Willow Creek DMA WC#12 5 years after the PFC assessment. Comparison of the monitoring data and the baseline data revealed that streambank stability had improved from 65 percent to 85 percent, and vegetation composition on the streambank had experienced a similar increase in stabilizing riparian plants.
4. The ID team may consider that both 85 percent streambank stability and the composition of stabilizing plants are now adequate for the reach.

5. The ID team would then observe the rest of the reach to determine if the remainder of the assessment is still valid, and if so, would now consider the reach to be in PFC.

If DMAs were not established and quantitative baseline monitoring was not completed following the PFC assessment, high-quality photopoints or other qualitative monitoring information can be used to help update the PFC assessment. This method generally works best where quantitative baseline data were not collected because the stream reach was a low priority for monitoring (e.g., the reach was located in a complex that is not sensitive to management and was rated as in PFC). If an assessment is updated, the ID team may also need to update related management objectives.

Step 7: Implement Adaptive Actions

If monitoring shows that the actions implemented are not making acceptable progress towards meeting the established goals or objectives, those actions should be modified. Monitoring would then be repeated to determine the effectiveness of those actions. In some cases, the original objectives may need to be modified to incorporate knowledge acquired from monitoring and adaptive actions or to address other changes to the reach.

3. Preparing for a PFC Assessment

Identify the Assessment Area

The PFC assessment can be conducted at various scales depending on information needs. It can be done at the landscape or watershed scale by either assessing all streams or a random sample of streams in the area or at the project level (allotment, grouping of allotments, fifth-order hydrologic unit code, etc.). PFC assessments are conducted to obtain information to answer specific management questions. A manager and ID team should determine what an assessment is to be used for and select an assessment area appropriate for the information needs.

Assemble an Interdisciplinary Team

A PFC assessment involves the art and science of understanding streams and their associated riparian areas with a watershed perspective. The assessment is intended to be performed by an ID team with knowledge of the attributes and processes occurring in the riparian areas being assessed. Team members should have strong observational and interpretive skills, experience collecting and evaluating quantitative monitoring data related to the attributes and processes addressed in the PFC assessment, and experience working with other specialists. They must be able to interpret the appearance of physical attributes to assess the functionality of each system correctly. The ID team is required because different disciplines must work together to accurately interpret existing information about the dynamic nature of riparian areas and how riparian attributes and processes change over time in response to management, climate, and watershed conditions. The ID team needs to have an understanding of riparian function attained from education, training, literature, time spent in the field with experienced personnel, and interpretation of the available information. The BLM provides several technical references (the 1737 series) for ID teams that are helpful for developing an understanding of riparian concepts.

ID team members should attend PFC assessment training prior to completing a PFC assessment. If untrained personnel serve on an ID team, they should be mentored by trained and experienced team members. A broad set of skills are necessary (collectively within the team) to conduct a PFC assessment:

- Knowledge of quantitative sampling methods that support the PFC assessment.
- Ability to gather information pertinent to the assessment: geographic information system (GIS) layers, remote sensing products, maps, monitoring data, etc.
- Knowledge of a watershed's geology, size, landforms, climate and weather patterns, hydrologic and fluvial processes, sediment dynamics, and how each affects streams in the region.
- Knowledge of reference conditions for assessment reaches, whether based on data or professional judgment.

- Ability to identify riparian plant species/communities of the region, including common riparian trees, shrubs, grasslike plants, grasses, and forbs, and the ability to use taxonomic plant keys.
- Knowledge of riparian vegetation (reproductive strategies, rooting characteristics, disturbance response and recovery, ecological amplitude, soil water/moisture tolerance and dependence on ground-water depths, expected distribution, structure, and abundance in different stream types, fluvial surfaces, and flooding regimes).
- Ability to determine soil texture, interpret soil features, particularly redoximorphic features, and relate soil texture and soil-water states to expected potential vegetation.
- Knowledge of geomorphic processes including sediment sources and storage/transport dynamics, influence of roughness elements, etc.
- Knowledge of stream attributes and bankfull indicators of a region and the ability to use streamgage data and appropriate publications to determine timing, frequency, and duration of flooding (local relationship between stream depth and time spent at depth over a prescribed period) and flood frequency (how often a flood of a certain discharge or stage is likely to occur).
- General knowledge of surface-water/ground-water interactions within river corridors including water tables and hyporheic zones.
- Ability to document assessment results in a report, make recommendations, and use PFC assessment results to inform collaborative adaptive management and monitoring.

Gather and Review Existing Information

Considerable information can be obtained by gathering, assembling, and reviewing past work, where available. PFC is a qualitative assessment, but quantitative data, photographs, and information from many different sources help the ID team recognize key attributes and interpret field observations correctly. Knowledge of historical conditions and interpretation of current information, combined with field observation of visual indicators (i.e., "reading the land"), lead the ID team towards a determination of potential, appropriate responses on assessment items, a trend determination, and an understanding of any current deterioration and expected recovery for the stream being assessed.

Each member of the ID team should review files and other known sources of information about the areas under investigation and share that information with the entire ID team. This review of existing information is critical to finalizing reach delineations and initiating a discussion of the potential of the reach. A file, which includes summaries of the pertinent information, is then developed for each assessment reach, or a set of reaches, within a project area.

The following sources may provide valuable information as the ID team prepares to complete a PFC assessment:

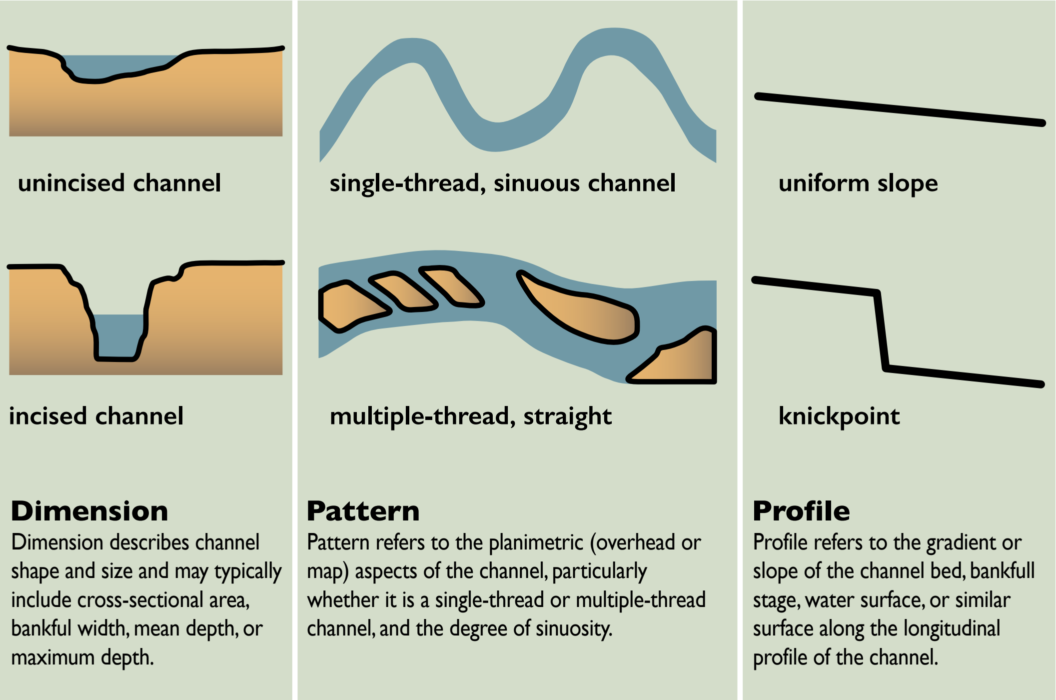
- A time series of aerial photographs (or other remote sensing products).
- Photopoints, historic photos, and any pertinent photos of past conditions.

- GIS layers and other information that will help with reach delineation (ecoregions, geology maps, watershed mapping, stream order, valley segments, current and potential stream types, general patterns of soil and riparian vegetation, management unit boundaries such as allotments and pastures).
- Topographic maps.
- Soil surveys and ecological site descriptions.
- Valley-bottom or stream-type classification measurements and mapping.
- Data from nearby weather stations and streamgages to understand precipitation and runoff patterns.
- Riparian and wetland plant lists.
- Riparian plant community classifications.
- Watershed assessment documents.
- National Wetlands Inventory maps.
- Ground-water reports.
- Species (animal and plant) lists that could be used to determine species habitat needs. These lists could shed light on riparian conditions that support or once supported those species.
- Land survey notes or other documentation of past/historical conditions.
- Previous assessment, inventory, or monitoring data, including interpretations/results concerning soil, water, vegetation, and wildlife, and other agencies' (e.g., state fish and wildlife) files for data.
- Information on reference areas (exclosures, preserves, slightly disturbed areas, well-managed areas with late-seral communities).
- Management records, including land use plans, allotment management plans, annual operating instructions, actual-use records, range inspection records, or other activity records of the assessment area.

Delineate and Stratify Reaches

A **reach** is defined as a length of stream with fairly uniform geomorphology (figure 3), hydrology, and vegetation. **Delineation** is an exercise performed by the ID team to identify reach breaks (i.e., the starting and ending points of reaches). Reaches are delineated on observable differences in geomorphology (valley form and channel dimension, pattern, and profile), hydrology (stream-discharge and sediment-load properties), soils, and vegetation (type and pattern of riparian plant communities) (USDA Forest Service 1992; Maxwell et al. 1995).

In contrast to delineation, **stratification** is a process of finding similarities among reaches, grouping reaches by commonalities, and classifying stream reaches into similar functional groups or strata that share a common set of attributes, processes, and management practices.



Dimension
Dimension describes channel shape and size and may typically include cross-sectional area, bankful width, mean depth, or maximum depth.

Pattern
Pattern refers to the planimetric (overhead or map) aspects of the channel, particularly whether it is a single-thread or multiple-thread channel, and the degree of sinuosity.

Profile
Profile refers to the gradient or slope of the channel bed, bankfull stage, water surface, or similar surface along the longitudinal profile of the channel.

Figure 3. Differences in dimension, pattern, profile, and other criteria are used to delineate reaches.

A **riparian complex** is a unit of land with a unique set of biotic and abiotic factors (Winward 2000), which is identified by changes in geomorphology, soil and sediment, stream gradient, waterflow features, and vegetation (USDA Forest Service 1992; Winward 2000). PFC assessments do not require formal and comprehensive riparian complex inventories; however, it is useful to understand how riparian complexes are identified. Riparian complexes typically follow a formalized naming convention based on common or prominent (overstory/understory) community type(s)—soil group—landform; an example would be a coyote willow (*Salix exigua*)/woolly sedge (*Carex pellita*)—Haploboroll—Trough Floodplain Riparian Complex.

Both reaches and riparian complexes are identified by the same set of biotic and abiotic factors. The distinction is that a reach is treated as a linear feature and emphasizes the properties of the stream channel, whereas a riparian complex represents a polygon or the entire width of the riparian area along a reach (Maxwell et al. 1995; Winward 2000). The terms may be used interchangeably with an understanding of the differences in their geometry. The "assessment reach" in a PFC assessment may be part of a riparian complex (e.g., when an individual complex is divided by fences or land-ownership boundaries into different management units), may coincide entirely with the extent of a riparian complex, or could be more than one riparian complex depending on management issues and environmental complexity.

Purposes and Objectives of Delineation and Stratification

The ID team must work through the delineation and stratification process to create the foundation for the assessment. Much depends on the delineation and stratification process, including (1) identification of potential natural condition by reach, (2) determination of

assessment approaches, (3) prioritization of the work plan, (4) extrapolation of findings for management purposes, and (5) selection of sites for subsequent monitoring of riparian areas.

Potential natural condition. The condition of a reach is evaluated in consideration of its potential (see chapter 4). The physical and ecological characteristics used to delineate and stratify reaches can provide information to develop descriptions of potential.

Assessment approaches. The ID team evaluates the assessment area and determines the type and degree of inspection a reach receives, dependent on time, budget, and availability of qualified ID team members. Other factors influencing the assessment approach include level of controversy, values at risk, sensitivity to management impacts, history and legacy effects of management practices and natural processes (floods, droughts, and wildfire), current practices and expected conditions, and accessibility of reaches.

Prioritization. Stratification permits prioritization of assessments as well as subsequent management activities and monitoring efforts. Prioritization parameters could include (but are not limited to) current success of management, applicability of federal and state laws and regulations, values inherent in a stratum, time since last assessment or until next planning effort, and amount of monitoring data and management information for the stratum.

Efficiency and extrapolation. Stratification permits managers to inventory, assess, and monitor a representative fraction of the land base. With proper stratification, land managers can work efficiently. The knowledge gained from inspection of representative areas can be extended and applied to other similar reaches. Extrapolation and inference among different types of reaches should be done carefully or not at all. One example of extrapolation or inference among reaches from different strata is a practice in which the ID team thoroughly inspects the complex that is most sensitive to the management activity within a pasture, allotment, or other management unit. Generally, if the most sensitive reach shows no adverse impacts from the management activity, then the condition of less sensitive reaches from the same pasture, allotment, or management unit rationally can be expected to be as good or better. Consequently, reaches in less sensitive strata might justifiably receive less attention than reaches in the most sensitive stratum.

Selection of DMAs. Stratification of reaches also serves to target the most sensitive, highest value or the most representative reaches for future monitoring. There is little benefit to monitoring sites that are highly resistant to change or to management activities. Details on the stratification process for DMA selection are provided in the MIM protocol (Burton et al. 2011.)

Delineation Process

Generally, the delineation of stream reaches is a two-step process. First, the ID team identifies tentative reach breaks using office reference materials (e.g., topographic maps, aerial photography, and any other physiographic and biotic information that delineates reaches). Tentative reach breaks are marked on a base map. Second, the ID team uses field observations to validate or modify starting and ending points of reaches. Reach breaks may be modified if delineations made in the office do not conform to physiographic and ecological observations made in the field.

Typically, reach breaks are based on:

- Geology (bedrock geology and valley substrate—colluvium, alluvium, bedrock).
- Geomorphic processes and properties including sinuosity, channel dimensions, drainage density, and relief ratios.
- The shape of the valley bottom, valley sides, confinement ratio, or stream entrenchment.
- Stream and valley gradients.
- Dominant sediment-transport characteristics: sediment volume and size, source, transport, or response reach (Montgomery and Buffington 1993, 1997; Schumm 1977).
- A major confluence, (i.e., one where the additional discharge or sediment contributed by the tributary is enough to substantially change the dimension, pattern, or profile of the channel it joins).
- Hydrogeologic features (e.g., depth to bedrock or valley-floor constrictions) that mark a relatively fixed boundary between losing and gaining stream reaches (figure 4).
- Hydrologic controls (including dams, diversions, etc.) that are big enough to alter the hydrologic regime.
- Riparian complexes.
- Pattern of dominant plant communities.

The ID team should explain the rationale used to delineate reaches so that subsequent teams can properly use existing reach breaks. Reach delineation is typically performed once and never repeated. Once reach breaks have been established, it is customary to continue using the same breaks. However, ID teams may want to validate previous reach breaks. Reach breaks are only modified if a major change in management

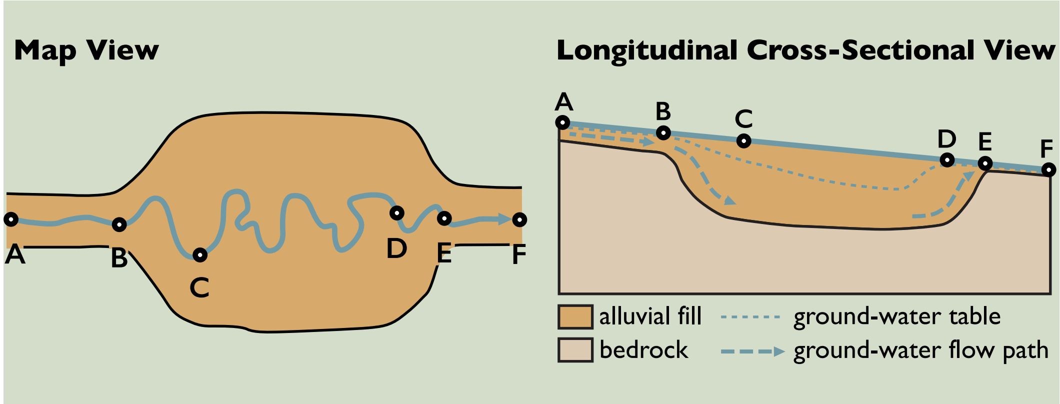


Figure 4. Hydrogeologic conditions in which valley constriction of alluvial fill (reach D-E) can cause upwelling of ground water and increased discharge to the channel (gaining reach), whereas widening of an alluvial valley floor (reach B-C) creates a larger alluvial reservoir that can absorb streamflow (losing reach). In the longitudinal cross-sectional view, shallow bedrock (reach A-B or E-F) can support hyporheic flow conditions, even during the low-flow season. Where the depth to bedrock increases (reach B-C), the capacity to absorb streamflow increases and a losing reach might form; in contrast, a decrease in the depth to bedrock (reach D-E) can force water to the surface (gaining reach). In both diagrams, streamflow is from left to right.

(e.g., elimination or addition of fence lines) or the environment (e.g., construction of a new, major dam or water-diversion structure) creates a need to adjust them, but these types of changes would be the exceptions to the general rule.

Management practicality. The assessment reach should be a manageable unit. As a general rule, it should be at least 1/4 mile in length as smaller reaches are generally impractical to manage and assess individually. Reaches with critical issues or special management concerns could be less than 1/4 mile long.

Ownership and management boundaries. Boundaries dividing land ownership, allotments and pastures, or other management units can and typically do serve as reach breaks. Even if the management is the same on opposite sides of a pasture fence, the fence may delineate a reach break for several reasons (e.g., different managers, livestock, or offstream water supplies).

Repeating complexes. Commonly, two or more riparian complexes repeat or alternate along a valley. For example, in narrow mountain valleys, the valley floor typically narrows and the channel becomes confined where it passes a fan from a tributary stream (figure 5, complex A). Upstream of the fan, the gradient is typically low, the valley bottom is slightly wider, and the channel is less confined (figure 5, complex B). Where an alternating or repeating pattern of riparian complexes is noted, the ID team will have to decide whether to complete (1) one assessment form for the entire valley, which comprises a repeating pattern of riparian complexes, documenting the rationale for grouping complexes; (2) one assessment form for each reach; or (3) two assessment forms with one specific to all the "A" complexes and one specific to all the "B" complexes within the valley. If one form is completed, then the relative percent of each complex within the reach should be noted, each complex should be described, and any conditions or trends specific to a complex should be noted. The method employed should best capture the riparian conditions and management implications for each complex.

Figure 5. Alternating lotic complexes within a valley segment reflect the influence tributary fans have on the main stream valley. Where fans are wide and dominate the valley floor, the riparian corridor is "pinched" and narrow (complex A). Upstream of fans, the valley bottom is locally flattened, allowing a broader expression of riparian communities (complex B). Streamflow is from right to left. (Image obtained from Esri World Image Service. World_Imagery - Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, AeroGRID, IGN, IGP, and the GIS User Community.)

Sometimes alternating lotic and lentic sections are located within one reach, such as where beaver ponds or wet meadows alternate with discrete channels that flow between ponds/meadows (figure 6). In this example, the ID team may use a lotic and lentic assessment form (see Prichard et al. 2003). Because the alternating complexes do not each exceed 1/4 mile in length, it is impractical to assess individual reaches. Instead, the ID team could complete one lotic assessment form to describe the condition of all "A" (stream–willow) complexes and one lentic assessment form to describe all "B" (wet meadow) complexes within a valley or management unit. Many different combinations are possible, and teams will have to decide which approach best suits their particular situation.

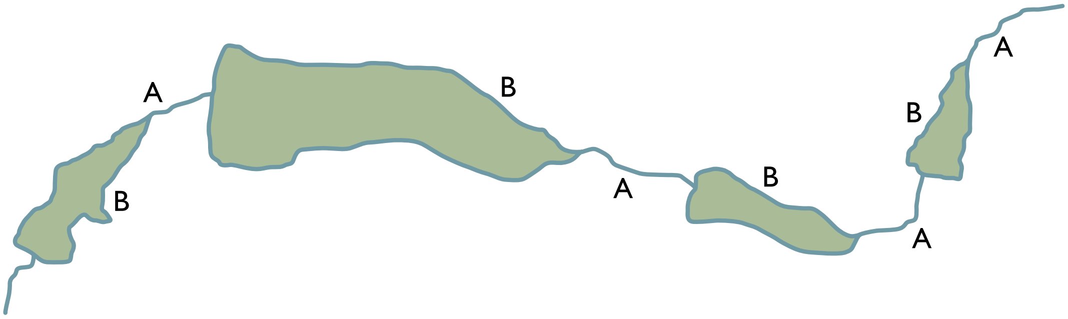


Figure 6. Lotic (complex A—stream–willow) and lentic (complex B—wet meadow) complexes can alternate and repeat within a reach.

Ecotones and gradational reaches. Transition areas (ecotones) can exist between riparian complexes. An assessment should not focus on conditions within an ecotone to make interpretations for the entire riparian complex. Also, the hydrologic, vegetative, and geomorphic attributes and processes might change gradually along the entire length of a reach such that there is no distinct starting and ending point to subdivide the reach. For example, if an alluvial reach is a losing reach, and the streamflow gradually changes from perennial flow to intermittent flow, the point in space and time where intermittent flow begins is not fixed. The ID team might establish a downstream reach break where intermittent flow is obvious and reflected in the composition of the riparian plant community; however, the team would note the gradational nature of diminishing streamflow and the gradual drying along the entire reach. The ID team would also use a gradational concept of potential in this reach.

Stratification Process

To stratify riparian areas into distinct groups, or strata, the ID team notes similarities and differences among reaches in the project area. For example, reaches can be stratified by slope, with low-gradient reaches segregated from steep reaches. Similarly, reaches can be stratified by substrate (bedrock from fine-textured alluvial reaches) to discriminate low versus high vulnerability to streambank alteration. Also, reaches dominated by communities of riparian shrubs should be differentiated from reaches that are dominated by herbaceous communities because livestock, wildlife, and human access to streambanks differ between these types of plant communities.

Whereas the delineation process emphasizes division of the stream system into small, discrete assessment reaches, the stratification process works in reverse by aggregating reaches with similar biotic and abiotic features into a stratum. The stratification process can aggregate reaches within a single valley and then build to progressively larger areas of interest, such as the subwatershed, watershed, ecoregion, or management area (see table 1). Managers can then use the stratified information to make rational comparisons and objective determinations about prioritization of assessments or restoration activities, location of DMAs, etc.

Table 1. Hierarchy of delineation criteria and possible data sources by stratification levels.

Stratification Level	Size	Delineation Criteria and Potential Data Sources
Geomorphic provinces (ecological life zones or similar)	10^2 to 10^3 mi^2; extent of Forest Service ranger district or BLM field office; 100,000 to few million acres	• Geologic maps (U.S. Geological Survey (USGS), state geological surveys). • Land resource regions or major land resource areas (USDA-NRCS 2006). • Ecoregions (Bailey et al. 1994; McNab and Avers 1994), available from USDA Forest Service and Environmental Protection Agency (Omernik 1987) or with an interactive mapmaker at the National Map website.
Watersheds	10^1 to 10^2 mi^2; average 227 mi^2; 40,000 to 250,000 acres	• Hydrologic unit codes and watershed boundary dataset (USDA-NRCS). • Stream order (National Hydrography Dataset) (Simley and Carswell 2009). Available from USDA-NRCS, the USGS, or the National Map website.
Subwatersheds	10^0 to 10^1 mi^2; average 40 mi^2; 10,000 to 40,000 acres	

Table 1 (continued). Hierarchy of delineation criteria and possible data sources by stratification levels.

Stratification Level	Size	Delineation Criteria and Potential Data Sources
Valley segments	hundreds of yards to tens of miles	• Geomorphic properties including drainage density, relief ratios, valley substrate –colluvium, alluvium, and bedrock (topographic maps and geologic maps). • Valley gradient, valley cross-sectional shape, and degree of valley confinement (1:24,000-scale USGS topographic maps, aerial photography). • Sediment-transport characteristics: sediment supply and size; source, transport, or response reach (sediment analysis). • Major tributary confluences with changes in sediment and water discharges (topographic maps and aerial photographs). • Hydrologic properties including runoff-contributing areas vs. recharge areas; flashy overland systems vs. dominantly baseflow-fed systems; losing from gaining reaches (USGS streamgaging stations and ground-water monitoring wells). • Spatial scales: stream-order hierarchy (topographic maps). • Elevation and climate with particular emphasis on the influence these features have on plant life zones and hydrologic budgets (topographic and ecologic maps, aerial photography).
Stream reaches and land types	1/4 mile to several miles	• Stream type, stream gradient, stream sinuosity, meander-belt width, stream entrenchment (topographic maps; aerial photos). • Channel and bed material (field examinations). • Hydrologic regime (USGS stream-gaging stations, field examinations). • Ground-water and surface-water interactions (gaining and losing streams) • Patterns of soil properties, especially soil texture, soil chemistry, soil-organic matter, and soil-moisture holding capacity (soil surveys, field examinations). • General patterns of plant communities (dominant vegetation species; riparian classifications, aerial photographs, field examinations). • Wetland indicator status: obligate wetland, facultative wetland, facultative, facultative upland, upland. • Lifeform: tree, shrub, graminoid. • Land ownership or management unit boundaries.

Plan and Time the Assessment Approach

The PFC assessment, in most cases, requires the ID team to physically inspect the stream reaches in the field or to at least sample various sites within a reach. The most effective way to accomplish a PFC assessment is for an ID team to do a complete reconnaissance of the stream by walking or boating the reaches. However, depending on the availability and quality of remote sensing tools (digital photos, aerial photos, GIS data, very large scale aerial photos, light detection and ranging (LIDAR) data, etc.), some reaches may be analyzed in the office using one or more of these tools followed by selective inspections of representative sites. As a general rule, an ID team should conduct random field verification on 25 percent of the reaches assessed by remote sensing (Clemmer et al. 1999). One example would be steep, brushy headwater streams or deep, narrow canyons that can be difficult to access and inspect physically. In these instances, remote sensing tools can be used effectively in conjunction with selective inspections of representative sites as needed to complete the assessment.

Other factors that may influence the assessment approach include level of controversy, resource values, sensitivity to management impacts, etc. All of these factors should be considered by the ID team to establish priorities for PFC assessments and to select the most suitable assessment approach. Regardless of the approach selected, the ID team should document the tools and approach used to complete the assessment. ID teams using remote imagery should have the appropriate experience using these tools.

The ID team should begin the assessments from the top of the reach or watershed and work downstream. Starting at the top allows for a more accurate assessment of the downstream reaches since the ID team has already observed upstream conditions. This approach helps the ID team assess factors that may be influencing downstream reaches (there may also be downstream impacts affecting upstream reaches, such as ground-water pumping). Also, the team should try to view the reach from an elevated area to get an overall picture of the reach.

The optimal time to complete the PFC assessment is during the growing season when the stream is at low flow and vegetation is most easily identified and evaluated; however, the PFC assessment can be completed effectively at any time of year when the vegetation, hydrology, and geomorphology can be readily identified. The assessment may be more challenging to complete during the dormant season or prior to leaf-out, when the stream is at high flow, or when the area has been recently grazed. In these cases, ID teams must be cautious to avoid allowing the superficial appearance of the riparian area to bias the assessment. If necessary, teams may need to postpone assessments until assessment items can be properly observed and interpreted.

ID teams should also be cautious about completing the PFC assessment immediately following high- magnitude flood events. In most cases, it is best to allow streams to at least start to adjust to these events before completing the assessment, if possible.

4. Conducting a PFC Assessment

Determine the Potential of the Reach

In the PFC assessment method, the condition of a reach is evaluated in consideration of the reach's potential. **Potential** is defined here as the highest ecological status a riparian area can attain in the present climate. This status is sometimes referred to as **potential natural condition**, or PNC, and is not to be confused with potential natural community, which is specific to the plant community. The word condition encompasses hydrologic, vegetative, and geomorphic attributes; therefore potential natural condition accounts for the hydrologic regime, the plant communities, and the channel and floodplain characteristics of the riparian area that exist at potential.

Ecological status is defined here as the degree of similarity between existing hydrologic, vegetative, and geomorphic conditions and the potential of a reach; the higher the ecological status, the closer the reach is to potential.

A determination of the potential of a stream reach can be challenging and often represents an "educated estimate." A detailed description of every attribute of potential can be very difficult (often impossible) and unnecessary for completing a PFC assessment. For the PFC assessment, the ID team must have a reasonable idea of the attributes and processes that are possible within the reach to ensure that the system will be gauged against what it can actually be. At a minimum, descriptions of potential must include an estimate of stream type(s) and plant communities.

When completing a PFC assessment, potential is identified for the assessment reach. Because the rationale for delineating and stratifying riparian complexes and reaches is based on physical and ecological uniqueness, the ID team should use information from the delineation and stratification process to develop descriptions of potential. Because a suite of plant communities (by definition) exists within a riparian complex and more than one channel form can occur within that complex (especially on larger streams and rivers), potential will commonly reflect a range of natural conditions that can exist when channel and riparian landforms are highly resilient and stable and dominant vegetation is composed of late-seral plant communities.

The identified potential should reflect what is possible within a reasonable timeframe in the present climate (generally no more than 50 years). Attempting to gauge current conditions against stream attributes and processes that may occur several decades or centuries (or more) in the future is conjectural and impractical for this assessment. For example, aggradation of an alluvial valley floor can drastically change riparian area potential but usually occurs over hundreds of years.

The ID team considers all the physical attributes and processes that affect stream function and identifies those that are most relevant to the riparian area being assessed. If the ID team does not develop an understanding of the attributes and processes that principally affect a reach, their judgment about PFC will be incomplete and may be incorrect. A partial list of physical attributes and processes that most affect any given riparian area and influence potential is included in table 2. This list is by no means complete.

An experienced ID team might be able to determine the channel characteristics and dominant vegetation at potential by walking the assessment reach and carefully noting the most relevant attributes and processes. When the ID team encounters a riparian complex that they have little experience with, they should use a combination of literature review, GIS analysis, and field reconnaissance to determine potential. Riparian vegetation classifications, where available, are a great source for much of the needed information. Riparian ecological site descriptions with state-and-transition models, where developed, can provide additional insight on the attributes and processes that affect the potential of a reach.

Table 2. Physical attributes and processes affecting stream function.

Geology, Geomorphology, and Topography	Climate and Hydrology	Vegetation and Ecology	Soils
Bedrock and surficial deposits Valley bottom geometry Watershed properties Bank stability Bed stability Sediment characteristics Channel characteristics -Cross-sectional area -Bankfull width -Width/depth ratio -Pattern -Sinuosity -Gradient Floodplain accessibility and extent	Weather and precipitation patterns including extreme events Discharge patterns including extreme events Runoff, infiltration, and baseflow relationships Position of water table Surface-/ground-water interactions Floodplain storage and release Flood modification Stream power Hydraulic controls Temperature	Community types and distribution Wetland indicator status of plants Disturbance dynamics and successional tendencies of plants Recruitment/reproduction Root characteristics	Soil type Soil texture Soil moisture regime Distribution of aerobic and anaerobic soils Soil organic matter Soil chemistry Bulk density

Geology, Geomorphology, and Topography

The geologic, geomorphic, and topographic characteristics of a drainage basin strongly influence the transport of sediment, water, and energy to and through channels; the places where sediment, water, and energy can be stored or attenuated; and the potential function of riparian areas. The principal geologic, geomorphic, and topographic attributes and processes that affect potential include:

- Type of bedrock geology and surficial deposits; depth to bedrock and thickness of alluvial fill.
- Valley bottom width, valley confinement, and the connections of hillslopes and alluvial fans to riparian areas and channels.

- Watershed properties (drainage area, drainage pattern, drainage density, basin shape, slope, relief, etc.) that influence basin hydrology (surface and ground water), sediment transport, and energy transfer and dissipation.
- Stability of channel banks and beds as determined by particle-size cohesiveness, channel geometry, and channel roughness elements.
- Characteristics of sediment such as supply, particle size, and particle shape.
- The dimension, pattern, and profile of the channel as expressed by cross-sectional area, bankfull width, width/depth ratio, sinuosity, pattern (single- or multiple-thread channel), and gradient.
- Extent and accessibility of the floodplain to attenuate floodflows and energy, store water, and capture sediment.

Climate and Hydrology

Climate, or the prevailing weather conditions and patterns over many years, and hydrology, both surface and ground water, influence the production, transportation, and deposition of sediment, the production of vegetation, and the modification of riparian and channel landforms. Consequently, climate and hydrology affect potential natural condition in several ways by controlling:

- The type, annual amount, and variability of precipitation, which in turn affect the annual amount and variability (peak, mean, and low flows) of stream discharge and influence hydrologic flashiness or complacency of a system.
- The depth to water table, seasonal fluctuations in water table, and the availability of water to hydric species.
- Ground-water and surface-water interactions, including losing and gaining stream reaches, and processes of ground-water recharge and discharge.
- The relative proportion of surface runoff, infiltration, and base flow throughout the drainage basin and within a reach.
- The annual range in temperature, particularly as temperature affects the freeze-thaw cycle, the physical production of sediment, and the storage and release of precipitation in the forms of snow, channel ice, snowmelt, and runoff.
- The typical weather patterns that maintain ordinary hydrologic conditions and the sensitivity of some systems to extreme values in temperature and precipitation, which can stress and destabilize riparian systems.
- The temporal and spatial distribution of stream power and delivery of energy to the stream channel and the riparian area.

Climate is affected by latitude, elevation, general circulation patterns, distance from marine influences and orographic effects, among other factors. Microclimatic controls can be especially pronounced in mountainous or hilly terrain where insolation (incoming solar radiation) varies significantly between north- and south-facing slopes. Differences in insolation can result in different plant communities, which are adapted to different soil-moisture conditions, evapotranspiration rates, and drought tolerances. Understanding climatic processes is vital to understanding which plant communities can occupy and thrive in different riparian areas or various parts of a riparian complex.

Vegetation and Ecology

Plants are the living materials that dissipate energy, capture sediment, build and bind banks, and provide forage and habitat to many species of animals. Determination of potential riparian vegetation and of the ecological requirements of riparian species requires knowledge of:

- Moisture requirements (i.e., the wetland indicator status) of riparian plant species and the distribution of community types in relation to water availability and soil characteristics.
- Plant responses to fluvial disturbances, such as flooding, deposition, and defoliation.
- Patterns of plant colonization and successional tendencies of riparian plants.
- Patterns of plant recruitment and reproduction.
- Root characteristics, particularly root strength, density, and depth and the ability of different types of roots to stabilize streambanks.
- Plant responses to fire and changes to fire regime.

Several riparian vegetation classifications are available for various states and regional areas. Riparian plant communities are best understood for perennial systems and for those intermittent systems that are slightly drier than perennial systems. In those intermittent systems that are slightly wetter than ephemeral systems, riparian plant communities are more highly variable and less understood. Determination of the potential riparian plant communities of a given reach is an ecological exercise that requires integration of the physical, chemical, and biological properties of a reach. Ideally, the ID team identifies and inspects the riparian complexes of reference areas to establish the natural variability in potential. Some reference areas might be within natural areas, within livestock or wildlife exclosures, or in administrative units, such as guard stations that are undisturbed by grazing. However, areas protected from grazing, recreation, or other uses are not necessarily appropriate reference areas. The initial reason for protecting an area might have been to restore a severely deteriorated stream segment, and such an area may still be in the process of recovering. Conversely, areas that have been grazed properly can provide an understanding of potential. Livestock grazing varies greatly in intensity, duration, and opportunities for recovery and, consequently, its influence on riparian functions. Therefore, the ID team should select and use reference areas with care. The reference conditions for potential can be based on data or professional judgment and should be documented.

Soil

Soil properties greatly influence the distribution and potential of riparian plant communities. The distribution of riparian plant communities is tied to various soil properties, including:

- Soil texture, especially in terms of water-holding capacity and its influence on the capillary zone immediately above the water table.
- Soil organic matter and its effects on bulk density, cation-exchange capacity, water retention, and pH.
- Soil chemistry, especially pH, reduction-oxidation potential, salinity, alkalinity, and cation-exchange capacity.
- Soil physics, especially bulk density and its effects on root growth, soil-moisture volume, and gas and water movement through soil.
- Distribution of aerobic and anaerobic soils, which is closely related to the water requirements of plants and the plants' abilities to extract vital gases.
- Soil-moisture regimes and the annual pattern of soil-water and reduction-oxidation states.

Assess the Reach

Delineation, stratification, and determination of potential first take place in the office. However, the ID team should use field observations to validate or modify reach breaks or determinations of potential. The location and description of each reach, as well as potential, should be recorded on the "Reach Information Form" as part of the assessment. Observations pertaining to attributes and processes used to determine functionality are recorded on the "PFC Assessment Form." A plant list, using the "Riparian Plant List Form" (or a similar form) is also recommended. The forms, as well as detailed instructions for completing them, are included in appendix A.

The PFC assessment protocol uses 17 assessment items to determine the functional rating category for each stream. These items are grouped into three categories—hydrology, vegetation, and geomorphology—and discussions are provided for each as it relates to the PFC assessment in chapters 5-7. The following information is also provided for each assessment item:

- The purpose of the assessment item.
- Observational indicators and examples useful for addressing the item.
- The supporting science used to derive the response to the item.
- Correlation with other items on the assessment form.

The assessment items are designed to address the common attributes and processes that have to be in working order for a riparian area to function properly. A "yes" response for an item on the form indicates that the attribute or process is working, a "no" response indicates that it is not working, and an "NA" response means that the item is not applicable to that particular reach. Examples of assessed reaches can be found in appendix E.

Many of the assessment items are closely related, which provides a system of checks and balances and requires users to closely consider related responses to ensure that they are consistent. For example, if item 14 (point bars are revegetating) is answered "yes" for a recovering system, item 4 should be answered "yes" because the riparian area is expanding. The items are numbered for the purpose of cataloging comments and the numbers do not declare importance. The importance of any one item will vary relative to a riparian area's attributes and processes.

The PFC assessment requires that the effects of high-magnitude, low-frequency events be taken into account. Although PFC is a barometer of how well a stream will endure a high-flow event, even the best functioning systems may experience major channel adjustments as a consequence of large, rare floods (i.e., those with a return interval greater than 25 years). Knowledge of historical riparian conditions is helpful to distinguish between channel responses to rare events and changes resulting from poor riparian conditions and poor land management.

The ID team should do a thorough job of completing each item and not dismiss the importance of an individual item just because it may not significantly influence the final rating. *How an individual item is addressed* often has a significant effect on future management, restoration, and monitoring actions—regardless of the functional rating.

The supporting science for some of the items is the same or overlapping. Explanations are provided with the most appropriate items, but some cross-referencing may be required.

If ID teams have difficulty resolving some "yes" and "no" responses, the assessment item(s) can be quantified to help resolve the issue(s). In some cases, the team may simply want to validate an item by collecting quantitative data. Appendix B describes techniques that are effective in quantifying the assessment items.

Apply Potential to the PFC Assessment

Potential is applied to the PFC assessment by considering each item on the assessment form relative to what it can possibly attain. When a "yes" response does not exist within the system's potential, the item is answered not applicable ("NA"). When the possibility does exist for a "yes" response, the ID team determines whether the item should be answered "yes" or "no" based on current conditions. A reach does *not* have to be *at potential* for an item to be answered "yes." The answer depends on the condition required to meet the definition of PFC and to maintain stability within an expected natural range of variation.

For example, item 6 states, "There is adequate diversity of stabilizing riparian vegetation for recovery/maintenance." If the *potential* of a particular reach is a combination of herbaceous plants and multiple shrub species and the *existing condition* is a dominance of multiple stabilizing herbaceous riparian species with only one shrub species, the item should be answered "yes" because even though the reach has the potential for more shrub species than is currently present, the composition of stabilizing plants is adequate for recovery/maintenance of the reach.

Applying Potential to the Assessment of Altered Stream Reaches

The need to assess stream reaches that have experienced human alteration is common. Understanding of altered potential requires an analysis of the type, spatial extent, and degree of human alteration. **Human-altered stream reaches** are defined here as those with relatively permanent human alterations that directly and substantially affect stream function. Such alterations can be caused by railroads, dams, diversions, channelization, levees, valley filling or placement of structures on flood-prone areas, roads, ground-water pumping, and related alterations that change the potential of the reach. Management activities such as livestock grazing, logging, forest stand treatments, and recreation are activities that can affect the reach; however, they are generally not permanent human alterations. For example, streams that have incised, due at least in part to grazing or road impacts, are not considered permanently altered by humans because not only can grazing practices or road management be changed, but the entrenchment stage of channel evolution can be caused by natural processes as well as management activities. Furthermore, incised streams can heal to regain riparian function with a change in management or environmental conditions.

Determining potential for altered systems can be complex. The ID team must carefully consider the type, spatial extent, and degree of the alteration to determine if and in what manner the potential has actually changed. If necessary, the ID team should describe the altered potential, which is the best possible ecological status and channel form that can be attained under permanent human alterations.

Because there are many unique stream alteration scenarios, and because the PFC assessment is a universal tool, creating detailed instructions applicable to all altered stream reaches would be impractical. The following questions, as well as the examples in appendix D, are provided to guide ID teams as they determine the potential of altered stream reaches:

1. Are alterations creating artificial channel conditions for a substantial part of the reach?

   Determining if the reach is altered so extensively that it is largely artificial will require the professional judgment of the ID team. This question is intended to eliminate from consideration those reaches that have been altered so substantially that, for the most part, they are no longer expected to provide natural stream functions. If the channel is largely artificial and the structures or activities are not expected to be removed, PFC would not be an appropriate tool for assessing the reach.

   In contrast, although all flow-regulated streams could be considered "artificial," many of them can still produce attributes and processes allowing them to function properly—they just may function differently than prior to the alteration (dam or diversion). In these cases, PFC would still be an appropriate assessment tool.

   An example would be a channelized reach where stream meanders have been removed and banks have been constructed or stabilized with hardened material (revetment) along most of the reach. In this case, the channel would no longer function as a stream, but rather as a hardened ditch. If the structure or activity is scheduled for removal (e.g., the ditch), the ID team determines what effect the removal will have on the potential of the reach (it may or may not be able to return to its original potential).

2. Are alterations present but the potential of the reach remains unchanged?

   If this is the case, the ID team assesses the condition of the reach by using the original potential. The mere presence of a human alteration does not necessarily change the potential of a reach. An example would be a stream reach where a few meander bends have been cut off due to road construction, creating only minor localized effects that have not changed the potential of the reach.

3. Are alterations present that have changed the potential of the reach (but have not created artificial channel conditions for a substantial part of the reach)?

   If this is the case, the ID team must determine what the altered potential is. Once the altered potential is identified, the ID team (a) documents that the potential of the stream reach has changed as a result of a human alteration, (b) describes the altered potential, (c) provides a rationale for how the altered potential was determined, and (d) assesses the stream reach in terms of this altered potential.

The ID team will need to use professional judgment in answering these questions and provide rationale for how these guidelines were used to determine if PFC is appropriate and, if so, how potential was established for the altered reach.

An example of a reach that has an altered potential ("yes" to question 3 above) would be a stream with channel dimensions consistent with a C stream type (riffle-pool channel with point bars) that is dominated by willow and birch with lesser amounts of herbaceous vegetation. A concrete dam is constructed and flows are highly regulated. Shortly thereafter, due to flow regulation, peak flows are attenuated and depositional events needed for the establishment of woody vegetation are considerably reduced. The downstream reach then slowly changes into an E stream type (narrow, very sinuous channel) with little or no woody vegetation. Potential for the altered reach would be addressed as follows:

1. Are alterations creating artificial channel conditions for a substantial part of the reach?

   No. While the streamflows are highly regulated, the channel can still produce attributes that will allow the stream to meet the definition of PFC.

2. Are alterations present but the potential of the reach remains unchanged?

   No. The potential has changed.

3. Are alterations present that have changed the potential of the reach (but have not created artificial channel conditions for a substantial part of the reach)?

   Yes, due to the installation of the dam, flow regulation has changed the stream from a C stream type, dominated by willow and birch with lesser amounts of herbaceous vegetation, to a narrow E stream type, dominated by herbaceous vegetation with few or no woody plants. The stream is still able to function properly, but cannot be expected to produce the same channel and vegetation conditions possible prior to construction of the dam.

If this stream were evaluated with respect to its potential (prior to the dam), it would never achieve the sinuosity, gradient, and width/depth ratio that are in balance with the landscape setting (item 3) and it will never return to a C stream type without removal of the dam or significant changes in the flow regime. Nor will it ever return to the woody-dominated system that existed prior to the construction of the dam and therefore must rely on herbaceous plant communities to "protect streambanks and dissipate energy" (item 11). Therefore, the altered potential of this stream is an E stream type dominated by herbaceous plants, and the stream will be evaluated with this new potential. Note that this does not imply that every dam will have this effect.

Applying Potential in the Context of Channel Evolution and Legacy Effects

Many reaches show the legacy of past management or past environmental events, such as extreme climatic and hydrologic events or catastrophic wildfires. Poor management and rare, high-magnitude natural disturbances can destabilize streams and transform them rapidly into an impaired condition that recovers gradually through a lengthy channel evolutionary process that might last for decades to centuries. Although details of the channel evolution process are complicated, and the process may occur in many ways, at different rates, and at different times, most channel evolution occurs through a general sequence of channel stability, channel incision, channel widening, aggradation, and stabilization (Schumm et al. 1984).

One channel evolution scenario is depicted in figure 7. In this scenario, **State 1** represents a high degree of bank stability, floodplain development, and plant community development and would be assessed as PFC.

State 2 may be in PFC or FAR. It may be assessed as PFC if bank-stabilizing vegetation is still dominant along the reach and other factors such as soil disturbance are not evident. **State 2** would be classified as FAR if bank-stabilizing riparian vegetation is not adequately dominant, undesirable upland species are abundant (e.g., Kentucky bluegrass, sagebrush, rabbitbrush), or excess soil disturbance is evident (e.g., collapsed banks from shear stress, trampling, or vehicle use). **State 3** would be assessed as NF because the stream channel is incising to a new base level, bank-stabilizing riparian vegetation is absent or sparse, and high streamflows cannot or rarely access the floodplain. Vegetation, if present, is often temporary due to its susceptibility to flood scour within the active channel.

State 4 is still NF. The channel continues widening, which allows flow energies to decrease. Alternate bars initiate floodplain formation. As in **state 3**, vegetation is usually temporary in the active channel due to flood scour.

State 5 may be assessed as FAR or PFC depending on condition of the most relevant hydrologic, vegetative, and geomorphic attributes. Establishment of a new floodplain and bank-stabilizing vegetation indicates progress toward functional conditions.

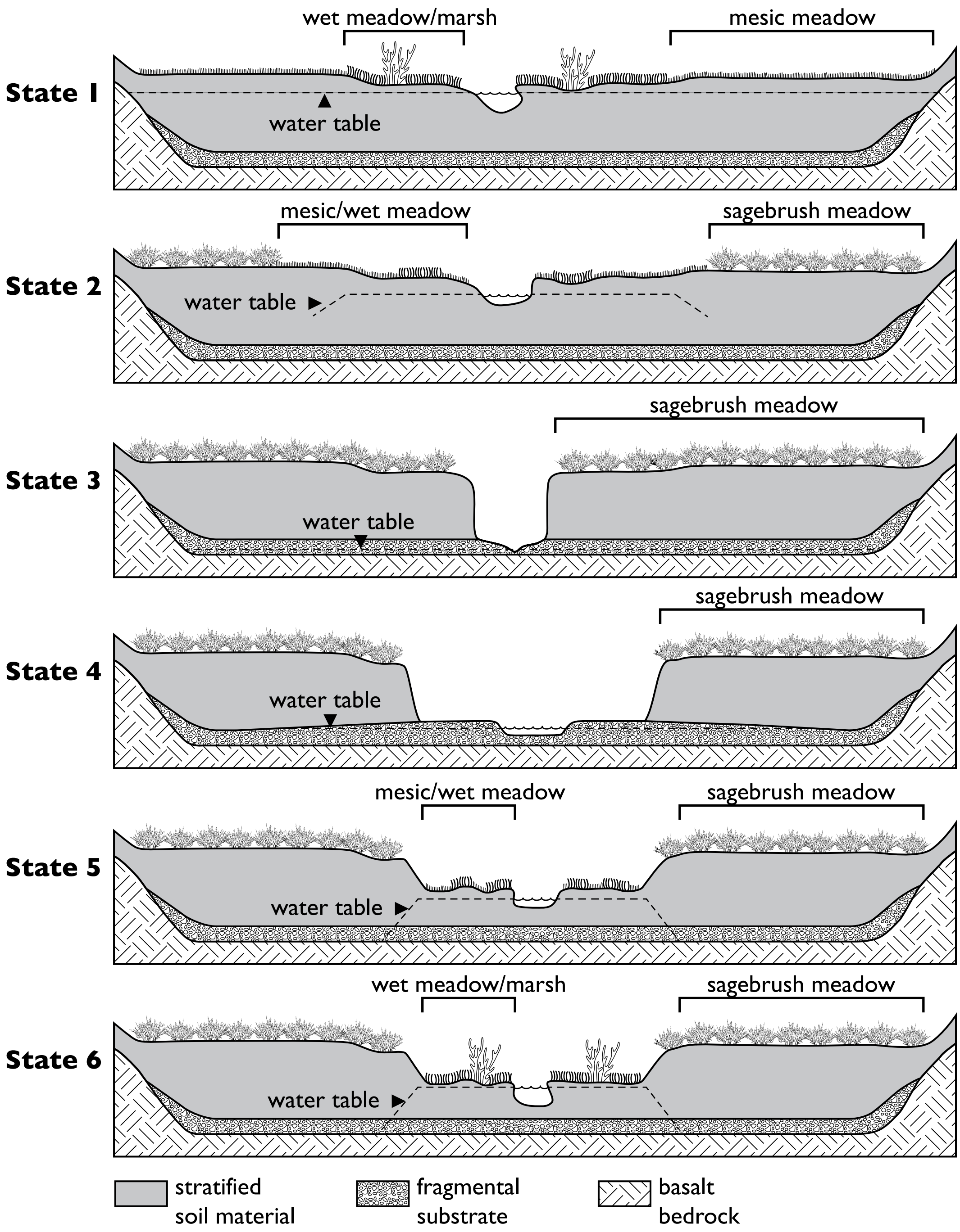


Figure 7. Succession of states for an alluvial valley-bottom type (adapted from Jensen et al. 1989).

State 6 is classified as PFC even though the riparian area may not have achieved the greater extent exhibited in **state 1**. Banks are stabilized and exhibit channel geometry similar to **state 1**. The floodplain has widened to the extent that confinement of peak flows is less frequent, and aggrading processes are modified because of the surficial extent of the floodplain and riparian vegetation. The largest differences between **states 1 and 6** are size and extent of hydrologic influence, which regulate size and extent of the riparian area. The floodplain in **state 1** is wider than in **state 6**.

One of the challenges in assessing highly degraded systems is discriminating between the potential of the system and realistic interim management objectives. In the scenario depicted in figure 7, **state 1** represents the potential in a predisturbance period. **State 1** still represents the potential during **state 2**, because the system has not yet crossed an ecological threshold, and a return to **state 1** is possible with proper management or favorable environmental conditions. However, in **state 3**, the system has crossed an ecological threshold—the channel is incised, the water table has dropped, the riparian area is radically narrowed, and dissipation of energy is greatly reduced in a highly confined channel. **State 6** represents the potential for **states 3, 4, 5, and 6**.

State 6 is not an altered potential because management actions can still restore riparian functions to a semblance of predisturbance conditions. There are no *relatively permanent human alterations that directly and substantially affect stream function* and, therefore, there is nothing that would constitute an altered potential.

The natural recovery period from **state 3** to **state 6** might take decades to centuries to complete. The riparian condition may be NF or FAR for the foreseeable future, but the ID team can evaluate the effectiveness of management by establishing interim objectives within a management timeframe of 10-25 years, which coincides with the typical lifespan of many management activities or plans. The assessment might focus on questions with management implications, such as "Do the management activities permit recovery of the system from **state 4** to **state 5** (or from **state 5** to **state 6**), or do these activities perpetuate a degraded condition or slow recovery?

Finally, **state 3** represents a condition that is the most impaired and farthest from potential and is so unstable that investment of resources and labor may be fruitless until the initial stages of recovery (i.e., **state 4**) are observed.

5. Assessing Hydrology Attributes and Processes

Hydrology is a fundamental aspect of stream function, relating to erosion and sediment transport, channel morphology, floodflow energy dissipation, and the ability of a riparian area to sustain appropriate and adequate vegetation. Items 1-5 address hydrologic attributes and processes that must be present and in working order for a riparian area to function properly:

- Item 1 addresses whether the stream has access to the floodplain and can spread out during high-flow events to dissipate energy.
- Item 2 determines whether beaver dams are present, and if so, whether they are stable. Stable beaver dams can increase aquatic habitat heterogeneity, assist in floodplain development, and can buffer the impacts of low-magnitude floods to downstream riparian areas. Unstable beaver dams may fail during high flows, contributing to the magnitude of the flow and increasing both downstream erosion and sediment deposition.
- Item 3 is specific to stream channel dimension, pattern, and profile. It evaluates whether the stream channel sinuosity, gradient, and width/depth ratio are in balance with the landscape setting and potential for the site.
- Item 4 focuses on the lateral extent of the riparian area. Degraded streams often have a narrowed riparian area as a result of lost contact with ground water, whereas an expanding riparian area typically indicates recovery.
- Item 5 addresses whether conditions upstream or within the upland drainage area are contributing to riparian impairment. It is not asking about the impairment or conditions of the uplands.

The ID team needs to collect background information and understand key concepts prior to completing the hydrology section of the assessment form. Quantitative information gathered in the office can help with the field assessment. For example, knowing expected stream channel dimensions will help the ID team determine the level of departure, if any, that they would then qualitatively document in the field. Gathering and reviewing information must be done prior to fieldwork and should include (but is not limited to):

- Calculating the drainage area from topographic maps, GIS, or other appropriate means.
- Developing an understanding of the bankfull flow and related geomorphic variables.
- Finding and using applicable hydraulic geometry or regional curves or both.
- Determining the presence or absence of dams, diversions, and ground-water wells.

The ID team can find information on the streamflow characteristics for their stream from USGS streamgage sites in the area. Three USGS websites provide flow information or regional regression equations to predict streamflow:

- StreamStats.

- USGS PeakFQ Flood Frequency Analysis based upon USGS Bulletin 17B.
- USGS National Streamflow Statistics Program that lists publications with regional regression equations by state and downloadable software.

The streamgage itself may not be on the stream being assessed, but if it is close enough and under the same geologic and hydrologic regime, information can be extrapolated. Information that can be obtained from streamgage data available on the USGS web page may include:

- Whether the assessment reaches are perennial, intermittent, or have interrupted reaches; streamflow hydrographs can show surface flow duration and periods when streamflow is nonexistent.
- Flood event timing (spring snowmelt, summer thunderstorms, or throughout the year) from hydrographs.
- Streams that have peak flows that are high but of short duration (tall and narrow hydrograph curve from thunderstorm-driven systems) or more moderate with a longer duration (wide hydrograph curves as in the case of snowmelt that occurs over a long period).
- Differences between summer baseflows and the relatively frequent floodflow events that fill the bankfull channel, as well as the difference between the 1.5-year and 100-year return-interval floods. These differences influence the potential channel form and riparian vegetation composition.
- Drainage area at the gage or at any other point along a stream.
- Floodflow frequency information to identify 1.5-, 2-, 5-, 10-, and 25-year return-interval floodflows; peak flow data can also inform the ID team when the last large flood occurred in the area. Following a large flood, a determination must be made about whether the observed conditions can be attributed to land management or are from the large flood event.

Someone on the ID team should be familiar with the concepts of Manning's equation and the continuity equation. These equations demonstrate some of the relationships between flow discharges or velocity and channel characteristics.

Streamflow energy (mean velocity) is affected by water-surface slope (gradient) and hydraulic roughness (Manning's equation). Mean velocity increases when gradient increases and vice versa. The hydraulic roughness has an inverse relationship with mean velocity. Manning's equation is:

$$V = k/n^{(R2/3\;S1/2)}$$

where V is mean velocity (feet or meters per second), k is 1.486 for English units (1 for metric units), n is Manning's roughness coefficient, R is hydraulic radius (feet or meters), and S is energy slope (water surface slope). Discharge varies by the product of channel cross-sectional area and water velocity. Therefore, an increase in either cross-sectional area or velocity translates into an increase in discharge. Furthermore, constant discharge can be maintained by inverse changes in area and velocity (i.e., an increase in area with a decrease in velocity, or conversely, a decrease in area with an increase in velocity.) If the change in cross-sectional area increases the hydraulic radius (approximately equal to the mean water depth), the velocity increases. The increased velocity occurs when a channel narrows and begins to deepen. The increased velocity and depth increase the stream power and its ability to erode the streambed (further discussed under items 3 and 16). The opposite occurs if streambanks erode laterally and the channel widens. The depth and mean velocity decrease, reducing the stream power and its ability to move sediment. The decreased velocity results either in stream channel aggradation (further discussed under items 3 and 17) or floodplain formation in an incised channel (further discussed under items 1, 13, and 14). Depending upon the stream condition and its potential, these actions can be describing either recovery or impairment of the channel.

The continuity equation can help identify the channel size needed to convey a known bankfull discharge. The continuity equation calculates flow discharge in cubic feet per second:

$$Q = A(V) \text{ or } Q = W(D)(V)$$

where Q is discharge, A is cross-sectional area of the channel, V is mean velocity, W is channel width, and D is channel mean depth. For example, if the ID team knows the bankfull discharge that fills the channel to the level of the floodplain (the incipient point of flooding), they can then estimate the cross-sectional area of the channel they are observing. This estimated value is divided into the known discharge to determine if the resulting mean velocity appears correct. If the channel is too small for the discharge, the calculated mean velocity obviously is going to be too high and vice versa if the channel is too large. This relationship between channel cross-sectional area and mean water velocity is an important means to assist the ID team in separating an active floodplain from a terrace (further discussed under item 1).

If the observed conditions do not agree with the values in the equations, the ID team needs to revisit the assessment items and their responses. These equations can also be used to help validate items in the geomorphology portion of the assessment (further discussion is included under items 13 through 17).

Item 1: Floodplain is inundated in "relatively frequent" events

Purpose

Item 1 involves determining whether frequent floodflows are capable of spreading out onto a low-lying area adjacent to the stream to dissipate energy, deposit sediment, recharge floodplain aquifers, and inundate riparian vegetation. The presence of adequate vegetation or landform (floodplain, canyon walls, etc.) to "dissipate stream energy associated with high waterflow, thereby reducing erosion and improving water quality" is one requirement for a riparian area to be in PFC. Important stream channel features used to address item 1 are shown in figure 8.

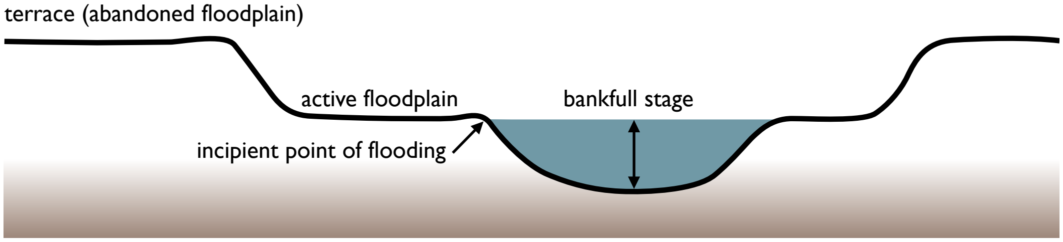


Figure 8. Stream channel cross section with important flow features identified.

Stream channels that are not landform controlled and have a low gradient (generally less than 2 percent) need a floodplain where floodflows can spread out and energy can be dissipated. The active floodplain is the level depositional area adjacent to the river channel that was constructed by the river in the present climate and overflowed during moderate flow events (Wolman and Leopold 1957; Leopold 1994). The flow that fills the bankfull channel to the edge of the floodplain is referred to as the bankfull discharge. This floodplain edge is referred to as the incipient point of flooding. When streamflow begins to spread over the floodplain, it is referred to as a flood. Water surface elevations below the incipient point of flooding are located within the bankfull channel.

Observational Indicators and Examples

Item 1 would be answered "yes" if relatively frequent floodflows can spread out on an adjacent floodplain. A floodplain will be recognizable throughout the reach (although it may be discontinuous). Visual evidence of frequent inundation of the active floodplain may include but is not limited to:

- Fresh deposits of fine sediment.
- Floodplain vegetation matted down or lying flat on the floodplain from overbank flow or by deposition of overbank sediment.
- Debris piled on the upstream side of tree trunks.
- High-water marks seen on rocks, trees, or other stationary objects and ice-rafted deposits on the floodplain.

The ID team should be careful when using flood debris deposited in streambank vegetation as evidence that a floodplain is present or that relatively frequent inundation has occurred. Less frequent, larger floods may deposit debris and litter in vegetation on an adjacent terrace, especially in incised channels. The flood deposits should be studied carefully to distinguish recent from relict and frequent from rare deposits. Older vegetation loses color and begins to decompose. Eventually floodplain vegetation will grow up through old flood deposits.

Item 1 would be answered "no" if a floodplain is not inundated by relatively frequent events. Visual evidence of infrequent inundation may include but is not limited to:

- A dam or diversion present within or upstream of the assessed reach preventing relatively frequent flood events from occurring.

- Downcut channels that prevent relatively frequent flood events from reaching the top of the channel and spreading out (figure 9).
- Vertical (or steeply angled) streambanks populated with upland vegetation rather than the expected riparian vegetation.
- A stream channel with an estimated cross-sectional area much larger than the dimensions predicted by the local regional curve.
- A stream channel that is much larger than what would be needed to convey the bankfull discharges (calculated using the continuity equation).
- Levees that prevent the moderate to high flows from accessing the floodplain.

Item 1 would be answered “NA” if a floodplain is not required for the riparian area to function. In some channels, floodflow energy is instead dissipated by channel roughness (boulders, cobbles, woody material) and landforms (friction from canyon walls) rather than spreading out on an active floodplain. Such channels include those that are naturally confined (located within narrow valleys or canyons) where there is insufficient width for a floodplain to develop or those that are located in steep valleys or canyons with high-water surface gradients (greater than 2 percent) that do not permit suspended sediment to settle out and develop floodplains.

Floodplain location should not be arbitrarily selected by the ID team—it must be properly identified, using information collected prior to the assessment, to determine if relative frequent floods are able to spread out and dissipate energy. Future ID teams must be able to identify what the past ID teams identified as the floodplain. Future monitoring depends upon an accurate and detailed description of the active floodplain. If two different fluvial surfaces are monitored through time, interpretations would be inconsistent due to observer error rather than from a change in channel structure or riparian condition.

In some stream types, field indicators may be sufficient to determine bankfull discharge. Other areas may require information gathered prior to the assessment as well as field measurements to substantiate bankfull discharge. The drainage area may be needed to determine if the bankfull discharge and bankfull channel dimensions (e.g., cross-sectional area) are properly identifying the floodplain in the assessed stream reach. Bankfull

Figure 9. The photo on the left shows an example of a stream that can no longer access its floodplain. Item 1 would be answered “no.” The photo on the right shows an example of a channel that has incised but has begun to rebuild a new floodplain in the inset channel. Item 1 would be answered “yes” for this type of situation.

discharge can be determined by flood-frequency analysis from available streamgage data. If assessments are to be done on streams that do not have gages, consult the USGS StreamStats website for state-specific protocols for estimating bankfull discharge. Prior to conducting the assessment, the ID team should determine if regional curves are available for the area or if curves developed elsewhere with similar characteristics would be applicable. Regional curves are developed from regression analyses of the relationships between drainage area and bankfull channel cross-sectional area, mean depth, width, and discharge. These relationships are derived from data collected at streamgages within a similar hydrologic province. Emmett (1975) provided the first calculated regional curves for bankfull discharge and channel dimensions for different drainage areas in Idaho. Dunne and Leopold (1978) used Emmett (1975) and other data to construct regional curves for different regions in the United States. The bankfull channel dimensions observed in the field might not exactly match those calculated from regional curves but are used as a general approximation.

Photos showing examples of bankfull stage and corresponding indicators in different stream types are available in chapter 5 of Rosgen (1996).

Supporting Science

Montgomery and Buffington (1993, 1997) recognized three primary channel reach substrates:

- Alluvial channels consist of materials that are readily transported by water and that can be deposited in the channel or on the adjacent floodplain when flow energy is diminished. Alluvial channels consist of materials ranging in size from boulders to sand, depending upon the stream's ability to move them during floodflows. Unconfined and low-gradient alluvial channels are expected to have a floodplain.
- Colluvial channels consist of materials that have been transported into the channel by gravity from the adjacent hillslopes. Colluvium is only moved by infrequent high flows. Colluvial channels generally do not have floodplains due to their locations in narrow or landform-controlled valleys.
- Bedrock reaches have little sediment deposition in the channel and represent high sediment transport capabilities (Rosgen 1996; Montgomery and Buffington 1993, 1997). Bedrock channels may or may not have a floodplain, depending on whether they are located in steep, narrow valleys (canyons) or in broad, flat valleys.

Wolman and Miller (1960) describe bankfull discharge as the discharge that is the most effective at maintaining the channel. This discharge erodes and deposits materials that provide for lateral movement of the stream channel and maintains the consistent morphologic characteristics and shape of the channel.

Bankfull discharge, which is exceeded by the maximum annual peak discharge in 2 out of 3 years, is considered a relatively frequent event (Wolman and Miller 1960). Recurrence intervals can vary from one stream to another within the same hydrologic region. The 1.5-year value provides guidance for areas where there is limited floodflow information.

There are also regional differences in bankfull discharge recurrence intervals. For example, bankfull discharge has a recurrence interval on average of 1.2 years in western Oregon (Castro and Jackson 2001). Moody et al. (2003) found that recurrence intervals for bankfull discharge fall between 1.0 and 1.8 years in Arizona.

Correlation with Other Assessment Items

Item 1 relates to item 13, (floodplain and channel characteristics adequate to dissipate energy). Item 1 can be answered "yes" if a developing floodplain is inundated frequently, but item 13 may be answered either "yes" or "no" depending on floodplain width.

Item 1 also relates to item 16 (stream system is vertically stable) because if item 1 is answered "yes" due to a consistent floodplain found through the assessment reach, the channel is not incising. In this case, item 16 would also be answered "yes." However, if the channel has recently or is actively incising and has abandoned the floodplain, both items 1 and 16 would be answered "no."

Item 2: Beaver dams are stable

Purpose

Beavers may be key agents of riparian succession because the dams they build act as hydrologic modifiers by changing local sediment, water, and vegetation dynamics. Item 2 documents whether beaver dams are stable.

Although beaver dams often benefit streams, they can breach and release floodflow energies that may result in downstream impairment or lowering of the water table. Beaver dams are more stable when they are actively maintained or when riparian vegetation establishes on the dam and helps hold it in place. Aerial photographs or past photopoints can show changes to beaver dams over time.

This item is intended to focus on the stability of existing beaver dams and not on whether beavers were historically present in a system.

Observational Indicators and Examples

If beaver dams are stable, item 2 would be answered "yes." Field indicators of maintained or stable beaver dams may include:

- Fresh wood cuttings (leaves are present or wood appears freshly cut) on the dam.
- Actively constructed ends on dams with no water pouring over or around either end to cause streambank erosion.
- Established riparian vegetation that appears to solidly support the dam; the ID team should note that new dams may not yet have riparian vegetation growing on them.
- Abandoned beaver dams vegetated with stabilizing riparian species and causing no impacts.

Beaver dams that are broken and not maintained would be considered unstable, and item 2 would be answered "no." Field indicators of unstable beaver dams may include:

- Broken and excessively leaking dams (beaver dams are not impermeable).
- Dam ends not anchored into both streambanks that can quickly erode and cause dam failure as a result of increased flow.

If beavers dams are not present, item 2 would be answered "NA."

Beaver dams often breach or fail during flood events. The ID team needs to examine the dam size and the amounts of water and sediment backed up behind it. If a dam that holds back a large pond breaches during a flood, it contributes additional flow and sediment and likely increase damage downstream over damage that would occur from a flood only. The release of trapped sediment could result in excessive deposition farther downstream, adversely affecting riparian function. This situation should be documented in the notes. A small, unstable dam may have a "no" answer, but the comments should reflect how much it would be expected to impact the overall functionality of the stream.

The ID team should also consider the size of the beaver pond and associated wetlands to determine if the lentic PFC assessment or a combination of the lotic and lentic PFC assessment items should be used to address important attributes and processes of that portion of the assessment reach.

Beaver dams in woody riparian systems will often be stabilized by vegetation that grows on or at the base of the dam (figure 10). Eventually the dam may be totally overgrown with vegetation (figure 11).

Although many beaver dams are constructed from woody material, others are built with only herbaceous materials such as cattail and bulrush stems (figure 12). These dams are typically low in stature, back up relatively small amounts of water, and commonly wash out during summer storm or snowmelt events. For these reasons, the ID team may still answer this item "no" but should clarify in the notes that dam failure would not be anticipated to result in riparian damage upstream or downstream.

Figure 10. A very stable beaver dam covered with a thick growth of herbaceous and woody vegetation.

Figure 11. A beaver dam totally overgrown with woody riparian vegetation. Water is still present behind the dam.

Figure 12. A low-stature beaver dam constructed with cattail and bulrush stems (photo courtesy P. Shafroth, USGS Fort Collins).

Supporting Science

Beavers are a natural component of riparian ecosystems. Prior to European colonization, it is estimated that there were millions of beaver dams in North America (Naiman et al. 1988; Butler and Malanson 2005; Westbrook et al. 2010). Beavers had a much larger influence on many lotic systems in the past than what they have today (Pollock et al. 2003). Beavers can convert riparian systems from lotic to lentic (Naiman and Melillo 1984; Andersen and Shafroth 2010).

Beaver dams can widen incised channels to allow floodplain formation. The dams back up water and reduce the stream gradient, which increases the stream's ability to meander or move laterally. The meandering causes lateral erosion and widening in the incised channel, which reduces flow energy and allows suspended sediment deposition for floodplain formation.

Water immediately upstream of a dam is at a higher elevation than water downstream, which raises the water table and allows riparian vegetation to establish and spread upstream of the dam.

Assessment of this item requires professional judgment. Active dams are usually considered stable, but over time, vegetation must become established to provide stability to the dam (Butler and Malanson 2005). However, dams that become unstable and fail can result in stream impairment and stream adjustments that include channel widening, lowering, and lateral migration (Butler and Malanson 2005) and can impact aquatic species (Stock and Schlosser 1991). Stable beaver dams are not necessarily resistant to flood events. Active beaver dams can be, and often are, breached or destroyed by flood events (Butler and Malanson 2005; Anderson and Shafroth 2010). Beaver dam failures typically occur after intensive or extensive rainfall or in association with high spring runoff from snowmelt (Stock and Schlosser 1991; Butler and Malanson 2005).

Correlation with Other Assessment Items

Item 2 is related to item 4 (riparian area is expanding) because elevated water tables and lower flow velocities upstream of the dams can promote riparian vegetation establishment and maintenance. Item 2 also relates to item 6 (stabilizing riparian vegetation) because the area upstream of a beaver dam may support different vegetation communities than the area downstream due to differences in soil texture and chemistry.

Item 3: Sinuosity, gradient, and width/depth ratio are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region)

Purpose

Item 3 pertains to whether the stream channel has the dimension, pattern, and profile expected for its landscape setting and potential. Sinuosity, gradient, and width/depth ratio must all be in balance for this item to be answered "yes"; if one of these is not in balance, this item is answered "no." Sinuosity, gradient, and width/depth ratio play important roles in how well a stream conveys water and sediment and dissipates energy. Channel classification tools such as those by Montgomery and Buffington (1997) or Rosgen (1994 and 1996) describe a range of characteristics for landscape settings.

These three attributes play a more important role in lower gradient alluvial streams (Rosgen's C, E, F, and some B stream types). Steeper gradient streams (A stream types) or streams of more moderate gradient that are confined laterally by their valley sideslopes (some B stream types) tend to have channels largely composed of erosion-resistant colluvial material or bedrock. In these streams, channel form is maintained by energy dissipation over and around woody material, bedrock, or large rocks (Montgomery and Buffington 1997) often arrayed in predictable step-pool sequences (Chin 1999 and 2002).

Sinuosity describes the level of the stream meandering observed through a valley. Sinuosity is the stream length divided by the valley length (figure 13).

Stream gradient, or water surface slope, is the steepness of the flow. It is measured by dividing the water surface elevation differences between the upstream end and the downstream end of the reach by the length of the reach, or "rise over run."

The width/depth ratio is the bankfull width divided by the mean bankfull depth (figure 14). The width/depth ratio can be directly measured in the field or carefully estimated.

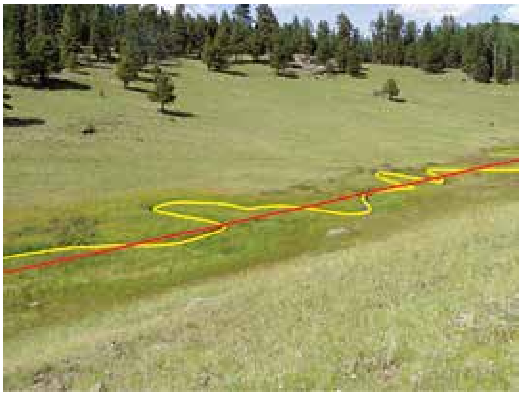


Figure 13. Stream length (yellow line) and valley length (red line) are used to calculate stream sinuosity.

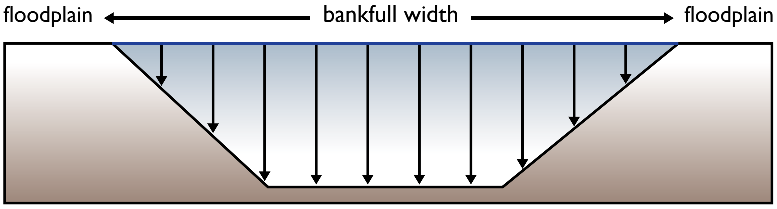


Figure 14. A stream channel cross section showing bankfull width.

Observational Indicators and Examples

Determining valley type and the current and potential stream types may help in assessing this item.

Sinuosity should be identified by the bankfull channel, not the low-flow channel. It can be evaluated from recent aerial photographs or in the field from a vantage point that allows the ID team to observe the entire reach. The ID team should be careful not to overestimate sinuosity if the active channel or thalweg is more sinuous than the bankfull channel.

Unless the stream is obscured beneath a canopy of woody vegetation, sinuosity easily can be estimated or measured from recent topographic maps and aerial photographs or calculated in GIS from the numerous programs on the Internet (Google Earth, ACME Mapper, National Hydrography Dataset, etc.). Obtaining precise measurements on very small streams may be difficult unless large-scale imagery is available. Sinuosity should be determined as part of the assessment process and then validated from visual observations in the field.

When the stream channel is located in a narrow canyon or valley that itself is sinuous, the stream and valley lengths could be very similar, with a sinuosity close to 1.0 (figure 15). In this case, the influence of sinuosity in the dissipation of stream energy is achieved by the resistance of floodflows against the canyon walls and by channel bed roughness.

Stream gradient can be determined to be in balance with the landscape setting by observing the stream sinuosity. If the sinuosity is too low, the gradient will likely be too high. Visual indicators of this imbalance can be:

- Active downcutting or headcut formation from increased flow energy from the steeper gradient.

Figure 15. The Colorado River in Dead Horse Point State Park, Utah, has a sinuosity close to 1.0 since the stream length (yellow line) and the valley length (red line) follow nearly the same path.

- Larger than expected or previously observed channel substrate as a result of increased energies moving the smaller material.
- Difference in bank height above the current water surface from one end of the assessment reach to another where it would be expected to be consistent.
- A stream channel that is losing access to its floodplain (relates to item 1).

The ID team determines channel width/depth ratio based upon bankfull channel dimensions. If the channel is very wide and shallow, the width/depth ratio is high. If the channel is narrower and deeper, the width/depth ratio is low. Streams that have beds and banks made of sand, gravel, or both tend to naturally have higher width/depth ratios than streams with clay and silt beds and banks of the same stream type (e.g., C stream types).

The ID team should observe the bankfull width/depth ratio throughout the reach. The observed channel width and depth will not vary depending upon streamflow. The bankfull width/depth ratio remains the same regardless of the current water level because it is measured or estimated from the expected bankfull channel dimensions (figure 14).

The bankfull width/depth ratio can be measured or estimated in the field when bankfull indicators are properly identified. Bankfull width/depth ratios should be estimated or measured:

- In a riffle rather than a pool in C, E, and F stream types (Lowham 1976; Rosgen 1996).
- In the middle of a rapid in a B stream type (Rosgen 1996).
- At the narrowest point between the base of a step and the upstream end of the downstream pool in stream types that exhibit step-pool features (A and G) (Rosgen 1996, figure 5.5).

If the riparian area is located within a wide, low-gradient alluvial valley (potential C or E stream types) and it exhibits moderate to high sinuosity and the expected stream gradient and width/depth ratios (potential C or E stream types), the answer to item 3 would be “yes.” Item 3 would also be answered “yes” for streams located in laterally confined valleys where large rock, bedrock, step-pool sequences, or boulders exert a dominant influence on channel form and energy dissipation.

If the riparian area is located in a wide, low-gradient alluvial valley and it exhibits low sinuosity, a higher than expected gradient, and a high width/depth ratio, item 3 would be answered “no.” These streams may also exhibit a lower sinuosity, a higher gradient, and a lower width/depth ratio than expected as a result of active downcutting. The answer to item 3 in this case would also be “no.”

Item 3 will never be answered “NA”; it will always have a “yes” or “no” answer. *All three elements have to be in balance with the landscape setting for this item to be answered “yes.”*

Supporting Science

Stream stability is defined as the stream’s ability, in the present climate, to transport the streamflow and sediment of its drainage area over time in such a manner that the channel maintains its dimension, pattern, and profile without aggrading or degrading. If the sinuosity, gradient, and width/depth ratio are not in balance with the landscape setting, the assessed stream is not likely to be stable and functioning properly. Stability allows for a range of variability over time and does not mean the same as rigidity.

The bankfull channel's width and depth dimensions have important roles in moving water and sediment. Boundary shear stress, measured in pounds per square foot, describes the force water is exerting on the channel bed (Knighton 1998). Boundary shear stress increases when either gradient or water depth or both increase. An increase in boundary shear stress also increases the stream's ability to move sediment. When both water depth and slope decrease, boundary shear stress decreases. When conveying the same discharge, as a channel deepens or shallows, the width must change accordingly. Often, impaired streams with high width/depth ratios will also have high bedload deposition in the channel. The ID team should note this observation to determine whether or not the width/depth ratio of a low-gradient stream is in balance or too high and whether the stream channel is able to carry its sediment load.

When a stream begins to incise and deepen as a result of excessive energy, the boundary shear stress increases, and in many cases, the gradient increases (item 16). The ID team should know the width/depth ratio and sinuosity values that are too low for the landscape setting. Lower than expected width/depth ratios may also be a sign of instability that can corroborate any visual evidence of downcutting. A degrading stream that is downcutting or incising will have a decreased width/depth ratio.

By contrast, in steep, high-energy streams and streams of moderate gradient confined by nonalluvial valley walls, channel form represents a balance between hydraulic erosive force and the resistance to erosion of the colluvial material or bedrock forming the channel boundaries (Montgomery and Buffington 1997; Church 2006). These streams are constrained laterally from developing sinuous channels and have beds and banks dominated by large colluvium from adjacent hillsides, bedrock, and in some cases, woody material. This large substrate is immobile during all but infrequent, large-magnitude flood events (Montgomery and Buffington 1997). Energy dissipation is accomplished by the hydraulic roughness provided by the large substrate and resistant valley walls.

Step-pool sequences, also found in these colluvial channels, dissipate energy by having a sinuous water path in the vertical dimension as water passes over steps (Montgomery and Buffington 1997). These sequences are analogous to the energy dissipation achieved by the alternating left and right movement of the waterflow in a horizontally sinuous channel (Chin 2002).

Correlation with Other Assessment Items

If item 3 is answered "yes" because the expected width/depth ratio is found through the assessed reach, the stream system is not incising (item 16). However, if the channel has recently or is actively incising and has abandoned the floodplain, both item 1 (floodplain frequently inundated) and item 16 would be answered "no." Also, if item 3 is answered "no" and there is evidence of excessive sediment in the channel, item 17 (stream in balance with water and sediment supplied) would also be answered "no."

Item 4: Riparian area is expanding or has achieved potential extent

Purpose

Impaired riparian areas recover and expand by capturing sediment, which aids floodplain development and improves floodwater retention. This recovery is generally first expressed by an increase in riparian vegetation. Item 4 relates to whether a riparian area is recovering or has recovered.

Item 4 has two parts. Part one is to determine if a riparian area is expanding. Part two is to determine if a riparian area has achieved potential extent. Either condition may result in a "yes" answer.

Observational Indicators and Examples

There are two mechanisms by which riparian expansion can occur during recovery: (1) as the water table rises, the riparian area can expand outward toward the valley hillslopes as riparian vegetation establishes in bare areas or areas occupied by nonriparian plants parallel to the channel (figure 16), and (2) streambanks can be rebuilt by vegetation growth and sediment deposition, which narrow the stream channel width and expand the riparian area inward toward the channel (figure 17).

Figure 16. An example of riparian area expansion.

Figure 17. Channel narrowing due to riparian area expansion. By 2008, the riparian area had achieved potential extent.

Surfaces for riparian area expansion can be created by flood-induced depositional processes, increases in sinuosity and associated subsurface or hyporheic flow paths, channel avulsions, or channel evolution of an incised channel, as in figure 7. An ID team may assess a riparian area early in its recovery with little riparian vegetation and determine that the revegetation process is working. An ID team may also assess a riparian area that is very healthy, has not experienced a large flood for some time, and is at potential extent. Both would merit a "yes" answer. Documentation of the rationale should include which visual indicators or data demonstrate expanding, contracting, or potential extent.

Visual evidence that a riparian area is expanding may include:

- An increase in cover of riparian species (e.g., obligate wetland and facultative wetland species).
- Establishment of riparian vegetation in recent deposits along a streambank.
- Replacement of upland species by riparian vegetation on sites where there is the possibility for expansion. The riparian vegetation would be vigorous and regenerating, whereas the upland species would be dying or showing declining vigor.

Some riparian trees and shrubs will have widespread germination of seeds, but few of the seedlings survive. To document riparian expansion, look for establishment of sprouts and young individuals of woody species.

If available, existing monitoring data, such as vegetation transects, greenline-to-greenline widths (a measurement of the nonvegetated distance between the greenlines on each side of the stream) (Burton et al. 2011), channel cross-section surveys, and repeat onsite and aerial photography, can be used to assess whether riparian area expansion has occurred.

Evidence that a riparian area is contracting includes:

- Persistence of redoximorphic features in soils that are now permanently unsaturated.
- Persistence of bare ground on geomorphic surfaces that should be revegetating with riparian vegetation.
- A decline in the water table with a resulting loss of riparian vegetation that is replaced by more drought-tolerant or upland vegetation (figure 18).

Evidence that a riparian area is at potential extent includes establishment of riparian vegetation on all surfaces that have the potential to grow riparian vegetation.

In some stream channels, riparian vegetation is not a factor in holding streambanks in place and contributing to the adjustment of channel dimension, pattern, and profile; channel form is predominantly controlled by the size and strength of the bed material (e.g., bedrock or boulders) or landform. In these cases, this item would be answered "NA."

Supporting Science

Riparian areas expand as a result of aggradation, along with other natural stream adjustments such as lateral migration, channel narrowing, and floodplain development. Potential riparian extent is largely determined by the valley bottom topography, soil variables, and water availability (height of surfaces above the wetted channel and depth to ground water) (Dwire et al. 2006; Law et al. 2000; Stromberg et al. 1996). Where there is a well-defined change in elevation, such as at a terrace riser, the community type changes can be distinct (Naiman et al. 2005).

Riparian recovery is usually first expressed by establishment of riparian vegetation. The vegetation slows water velocity of overbank flows and runoff from adjacent landforms, resulting in deposition of sediment, creation of sites for water storage (Elmore et al. 1994), and improvements in streambank and channel stability (Hayashi and Rosenberry 2002; Tabacchi et al. 2000), which in turn keep the channel connected to the floodplain. Riparian

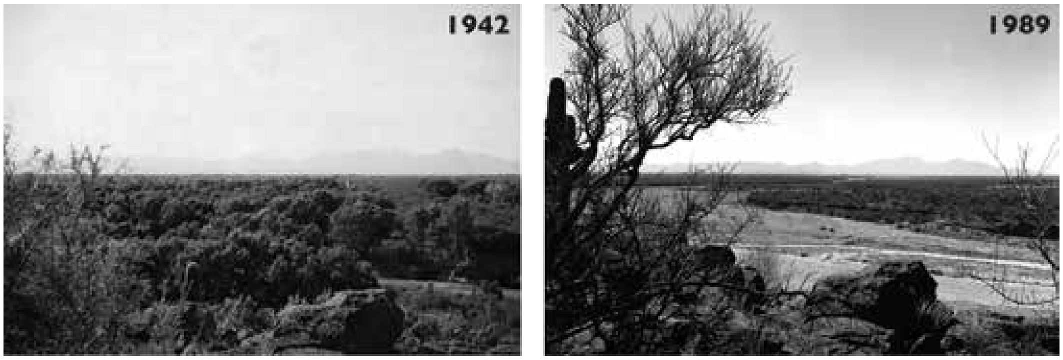


Figure 18. Paired photopoints of the Santa Cruz River south of Tucson, Arizona. The water table has declined more than 100 feet due to ground-water pumping, and this pumping appears to be the principal cause for the decrease in riparian vegetation. Photos by Robert H. Webb (Alley et al. 1999).

vegetation increases infiltration (Weixelman et al. 1996 and 1999; Bharati et al. 2002) and soil-moisture retention capacity by adding organic matter and creating macropores via root channels. Effective infiltration then leads to saturated ground-water flow, raises the water table near the streambank (Ponce 1989), and slows the release of subsurface waters to surface waters (Barber 1988). Over time, all these processes lead to further expansion of riparian vegetation until potential extent is achieved (Gebhardt et al. 1990).

Some riparian species, such as hardstem bulrush, aquatic sedge, and creeping spikerush, expand when their rhizomes root into the streambed and thrive in standing water. They capture sediments to rebuild streambanks and narrow a channel.

Naiman et al. (2005) list the alteration of flow regimes as the most serious contemporary threat to riparian areas. Both high- and low-flow events present critical stresses and opportunities for riparian vegetation maintenance and establishment. Contraction of riparian area extent can occur as a result of flow stabilization, loss of seasonal flow peaks, prolonged low flows, lowering of the water table, altered inundation duration, or accelerated flood recession (Poff et al. 1997). Surface-water interactions are commonly understood, but ground-water interactions are more complex.

When a well is pumped near a gaining stream, ground water that would normally flow to the stream can be captured by the cone of depression, and the well can also drain water from the stream towards the well (figure 19). In a low-flowing stream, the capture of streamflow can cause the stream to go dry in a relatively short time (a few months), depending on the duration and magnitude of the lowered water-table level adjacent to the stream. These effects will occur not only for wells located near a stream, but also for wells a mile or more away if the stream and the wells are in sediments that are hydraulically connected, such as in basin fill composed of unconsolidated sand and gravel deposits. A stream may undergo changes from a gaining stream to a losing stream and finally to a disconnected stream, where the ground-water level is no longer in contact with the stream (figure 20) (Winter et al. 1998; Barlow and Leake 2012). The ground-water level in the riparian area may fall to a level too deep for riparian vegetation to survive, resulting in loss of riparian vegetation and replacement by upland vegetation within the potential riparian corridor.

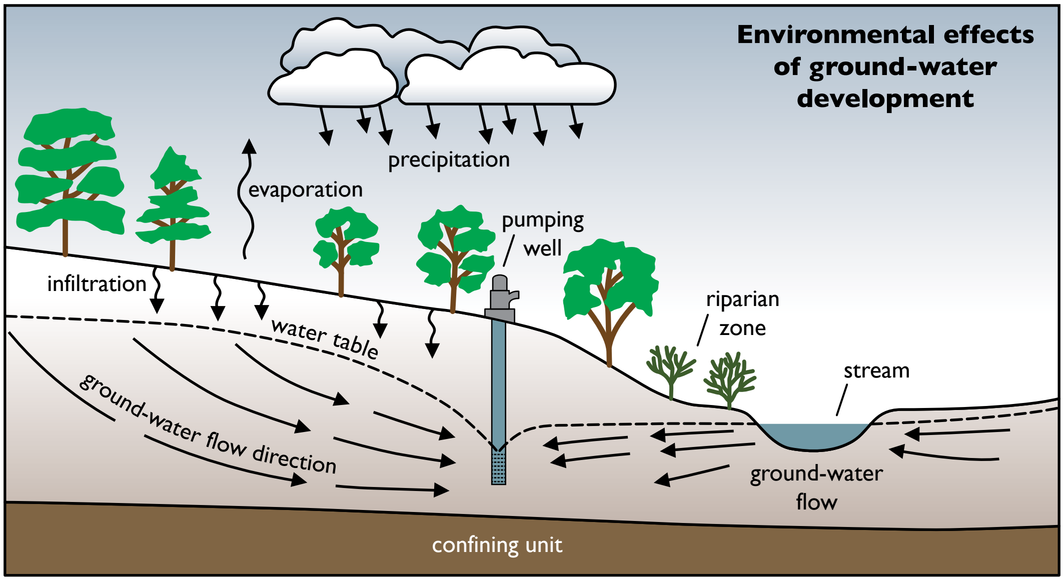


Figure 19. Drawdown effects on streamflow and on the riparian area from a pumping well (adapted from USGS 2012).

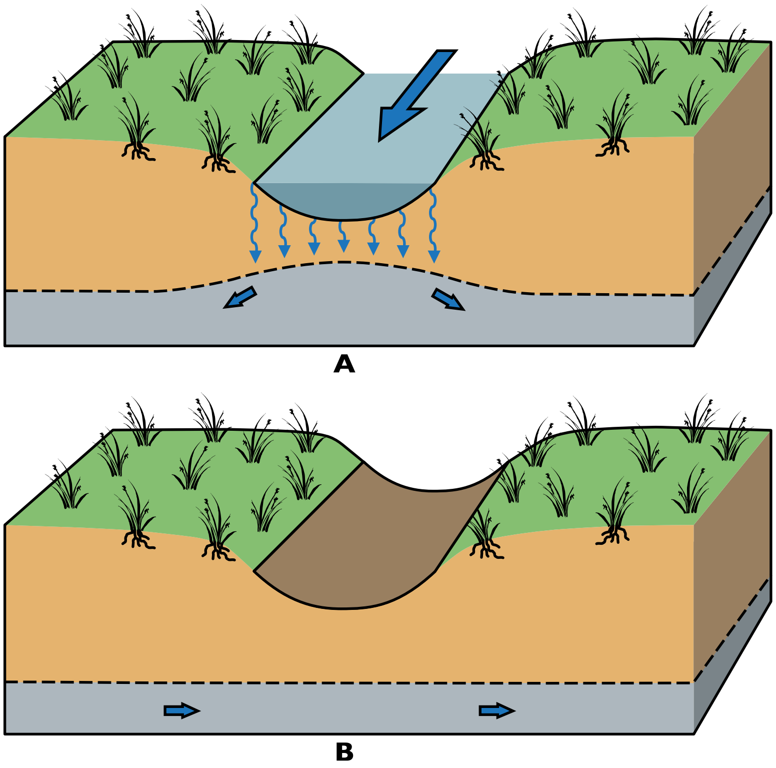


Figure 20. Disconnected stream reaches are separated from the shallow ground-water system by an unsaturated zone. In diagram A, the stream is hydraulically disconnected and is losing water to the underlying water table. If the stream losses are great, a ground-water mound could build up underneath the stream. In diagram B, the water table has declined further, and the stream has gone dry (modified from Winter et al. 1998).

Studies looking at repeat photography, qualitative surveys, and quantitative surveys have documented riparian area expansion or contraction (Alley et al. 1999, Borman et al. 1999; Groeneveld and Griepentrog 1985; Kozlowski et al. 2010; Newman and Swanson 2008; Sipple and Swanson 1996; Smith et al. 1991; Stromberg et al. 1996; Webb and Leake 2006).

Correlation with Other Assessment Items

Item 4 is related to item 3 (sinuosity, gradient, and width/depth ratio in balance) because for low-gradient alluvial streams, expansion of the riparian area may coincide with channel narrowing as documented by a decrease in the width/depth ratio. If the riparian area expands, bare areas will have younger age classes of plants growing on them from recent colonization or revegetation, which relates to item 7 (recruitment of stabilizing vegetation). Riparian expansion also indicates maintenance of soil moisture characteristics (item 8).

Item 4 also relates to item 13 (floodplain and channel characteristics adequate to dissipate energy) because often it is the dissipation of energy that allows for riparian area expansion. Additionally, item 4 relates to item 14 (point bars revegetating) because for stream types with point bars, the tops of point bars are a critical location for the establishment and expansion of stabilizing vegetation for maintenance of channel characteristics.

Item 5: Riparian impairment from the upstream or upland watershed is absent

Purpose

Item 5 addresses if there has been a change in the water or sediment supplied to the reach being assessed from its watershed and if that change is resulting in riparian impairment. The watershed of a stream reach includes its entire contributing upstream basin (upland areas adjacent to the riparian area, as well as upstream reaches and their uplands). This item addresses whether the watershed is contributing to impairment of the riparian area; it does not address the condition of the watershed. It provides the opportunity to differentiate, if possible, between any impacts from the watershed versus direct impacts to the riparian area being assessed.

A "yes" answer provides a positive indicator of functionality. A "no" answer means the watershed is contributing to riparian area impairment.

Observational Indicators and Examples

In a step-by-step evaluation process, an ID team would first determine if there is evidence of impairment in the riparian area. If there is no evidence, then item 5 would be answered "yes." Disturbances in the uplands can occur without causing major changes in discharge, timing, or duration of streamflows or impairment to a riparian area. If there is evidence of impairment, then the source would need to be determined:

- If impairment is from a local (in situ) source, item 5 may still be answered "yes."
- If impairment is from an upstream/upland source, then item 5 is answered "no."

Potential upstream/upland sources should be identified. Sediment sources in the watershed can be investigated through analysis of aerial photography, either when preparing for the assessment (gathering and reviewing existing information) or after the field portion of the assessment. The cause-effect relationships between upland conditions and channel/riparian area impairment should also be identified.

The visual indicators for item 5 are not subtle. If the watershed is contributing to riparian impairment, the channel form is altered by excessive deposition or channel incision. There can be natural events in the watershed, such as wildfire and subsequent sediment delivery to channels, that cause changes to channel form and would merit a "no" answer with an explanation of the severity of the "no" for that system.

Evidence that excessive sediment is from uplands or upstream reaches and not associated with direct impact to the assessment reach's streambanks may include (1) a streambank dominated by healthy riparian vegetation where braiding is present in what should be a single-thread channel; (2) point bars overloaded with sediment; or (3) altered sinuosity because of fan deposits from excessive upland erosion. If these characteristics are present, the answer to item 5 would be "no."

Figure 21 shows an example of a reach where this item should be answered "no." The reach had many mid-channel bars and overloaded point bars (note the steepness of the point bar slope) due to receiving excessive sediment. The mid-channel bar fomations are indicators of deterioration for this stream type. In this example, the ID team determined excessive erosion is occurring from both the streambanks of the reach being assessed and from mine tailings that are being delivered to an upstream reach. Item 5 would be answered "no" since an impact in the watershed is contributing to riparian impairment.

Figure 21. An example of a mid-channel bar.

Item 5 will never be answered "NA"; it will always have a "yes" or "no" answer.

Supporting Science

The ID team determines if impairment is present and if it is related to some in situ channel/riparian disturbance or to some impairment elsewhere in the watershed that is being transmitted to the assessment reach. The stream channel is the primary conduit of water, sediment, and other materials derived from the watershed and is a possible sediment source from eroding streambanks. A channel system is said to be in equilibrium when, through a period of years, the shear stress is sufficient to transport the sediment delivered to the channel and neither excessive deposition nor excessive erosion is taking place, which leads to a dynamic form of stability in the cross-sectional and longitudinal profile. Equilibrium does not imply absolute rigidity, but rather that the stream and riparian area are resilient and able to adjust and recover from many natural disturbances. Equilibrium also implies that naturally formed channels may experience little net change in channel form at reach and larger scales, despite numerous local changes. Changes in shear stress, sediment supply, and resistance of bed and bank materials to cutting can disrupt the equilibrium of the channel system and cause excessive erosion or deposition in the channel, which can lead to impairment of the associated riparian area. Hence, the condition of the watershed can greatly affect the condition of a stream reach and its associated riparian area (Naiman 1992; Satterlund and Adams 1992). The change in equilibrium can be illustrated by the Lane/Borland balance, a conceptual model that portrays processes of aggradation and degradation (channel incision) in terms of changes in sediment supply, sediment size, discharge, and gradient (see chapter 7).

Interpreting the equilibrium concept requires an understanding of watershed history, including both natural events and land-use practices, and the adjustment processes active in channel evolution. Channel adjustments seen today may be in response to something that happened in the watershed 50-200 years ago that is still being transmitted up or down the stream system.

Correlation with Other Assessment Items

Item 5 is related to item 3 (sinuosity, gradient, and width/depth ratio in balance) because impairment from the watershed involves excessive erosion or deposition, which affects channel form. It is also related to the sediment being supplied and transported in a reach, which is examined in item 17 (stream in balance with water and sediment supplied).

6. Assessing Vegetation Attributes and Processes

Items 6-12 address vegetation attributes and processes that need to be in working order for a riparian area to function properly. Although most streams affected by management activities require vegetation to function, some landform-controlled reaches (e.g., steep, boulder-dominated streams) may not; therefore, many of the vegetation items for these types of reaches would be answered "NA."

Factors such as the kind, proportion, and amount (cover or density) of vegetation in the riparian community contribute to stream and riparian function. The linear distribution of stabilizing vegetation species along the stream margins is the primary factor affecting the development and protection of streambanks and stream bars. The lateral distribution of vegetation across the riparian area determines the site's ability to accommodate periods of floods (overbank flows) and drought.

There is a progression in plant density and plant community development, from the complete absence of stabilizing vegetation species to the development of stabilizing plant communities throughout a riparian area, approximating ecological potential. Thus, all of the vegetation items are closely correlated to one another because they represent different stages in this progression:

- Items 6-8 address the kinds of plants in the riparian area and if there is recruitment of young plants and maintenance of other age classes. These three items seek to determine if the right plants are present and if they are reproducing. They do not address how many plants are there, just whether the plants are present because the presence of key riparian plants is the first step in the recovery process.

- Item 9 relates to whether the riparian plants identified in items 6-8 have progressed to the point that stabilizing species are forming recognizable and distinct communities *on the streambank* (the ID team should note that item 9 is specific to the streambank, whereas items 6-8 address the entire riparian area). This phase is the next logical development after vegetation establishment and is key to determining whether recovery is imminent. Item 9 also does not address whether the amount of stabilizing plants is adequate, only whether stabilizing plant communities are present.

- Item 10 focuses on whether the plants present (addressed by the previous items) are vigorous. This is another critical attribute for plant community establishment, expansion, and persistence necessary for recovery and maintenance of a riparian area.

- Item 11 is important for synthesizing the vegetation items assessed in that its intent is to determine if there is an adequate *amount* of vegetation to protect banks and dissipate energy during moderately high flows. The amount of vegetation is expressed by the distribution of stabilizing riparian plant communities present *on the streambank*. The amount is the last item in this sequence of recovery—vegetation has to first become established, reproduce, and form communities before there is enough cover to protect streambanks.

- Finally, item 12 asks if there is an adequate source of live trees for large or coarse wood to be available for streams that depend on woody material to function properly in the future.

Completing a riparian plant list (appendix A) is an important preparatory step to addressing the vegetation items. Dominant vegetation, stabilizing species, and diagnostic species for ecological site descriptions or other classifications should be recorded to help indicate or refine potential. The wetland indicator status (Lichvar et al. 2014) and the greenline stability rating (Winward 2000; Burton et al. 2011) for each plant should be recorded. Although important, simply recording plant species is not sufficient to accurately address the vegetation items on the PFC assessment form. The plant specialist(s) on the ID team must understand plant attributes, such as the growth, distribution, and reproductive habits of those species, and how each functional vegetation group influences stream function.

Facultative upland and obligate upland vegetation may occur interspersed naturally with obligate and facultative wetland species in some situations. Common situations include the outer margin of almost all riparian wetland areas, intermittent streams, and "problem wetlands" (Prichard et al. 2003). A mix of upland and wetland species may also occur on well-drained floodplains of "flashy" systems (systems that exhibit sudden, sometimes extreme flows associated with localized convective storms), where obligate and facultative wetland species often establish on regeneration sites at the channel edge or even within active channels. Some forest species, such as Douglas fir in the Pacific Northwest and many hardwoods in more mesic climatic regimes, may occur on both upland and riparian environments but often have a higher growth rate in riparian environments and may also have different associated species.

Riparian vegetation may also include invasive species or noxious weeds. Water is an excellent dispersal agent for seeds, and weeds can become established especially early in the recovery process. Because the PFC assessment focuses on the physical function of the stream, the presence of nonnative invasive or noxious weeds (although undesirable) does not necessarily preclude the achievement of PFC. Some invasive species possess good bank-stabilizing properties. The effects of noxious weeds in the riparian area may be symptomatic of other problems in the system and would be addressed in the appropriate assessment items. For example, tamarisk or reed canarygrass monocultures tend to negatively impact the natural sediment regime (items 1, 3, and 17) and vegetation diversity (item 6). Nonnative invasive species and noxious weeds should be noted in appropriate detail on the assessment form.

Vegetation items are designed both to help diagnose the functional rating and interpret recovery potential. As an example, there may be a situation in which item 9 (stabilizing plant communities capable of withstanding moderately high streamflow events are present along the streambank) is answered "yes," and item 11 (adequate amount of stabilizing riparian vegetation is present to protect banks) is answered "no." If the trend is up, management is allowing for stabilizing riparian plant community formation. In this example, improvement is likely imminent by either continuing current management or by making some modifications. A downward trend can be a red flag. In a stream reach where items 9 and 11 are both answered "no," recovery is not evident, the problem is likely severe, and a different management approach may be necessary. Although both of these streams would likely be rated as FAR, the management approach may be very different for each reach.

Item 6: There is adequate diversity of stabilizing riparian vegetation for recovery/maintenance

Purpose

Recovery or maintenance of most lotic riparian areas requires the presence of plant communities that contain stabilizing riparian vegetation. **Stabilizers** are plant species that (1) become established along the edges of and in streams, rivers, ponds, and lakes; (2) commonly have strong, cordlike rhizomes as well as deep fibrous root masses; and (3) have coarse leaves and strong crowns, which, along with their massive root systems, are able to buffer streambanks and shorelines against the erosive forces of moving water. Although they generally require hydric settings for establishment, some may persist in drier conditions once they have become firmly established (Winward 2000). Many of the sedges, rushes, and willows are considered stabilizers (common examples include Nebraska sedge and Geyer willow). In contrast, species such as brookgrass, watercress, redtop, and Kentucky bluegrass have shallow roots and relatively weak stems and are much less able to buffer streambanks.

Item 6 addresses whether a sufficient number of stabilizing plant species are present (not whether all the stabilizing species an area can support are present). For most riparian areas, this means having two or more stabilizing riparian plant species present for each life form (herbaceous and woody) as defined by Winward (2000) or Burton et al. (2011), depending on reach potential.

The presence of only one stabilizing species often makes a site vulnerable to disease or extreme changes in climate, which may result in impairment of an area. Many riparian plant communities are dominated by a single stabilizing species, but at the reach scale, a complex of plant communities is most often expected. There are some areas with only one major community type dominated by a single stabilizing species even at potential; however, these are generally not common (at the reach scale) and are usually limited as a result of a unique soil property, vegetative characteristic, or water regime.

Observational Indicators and Examples

Many streams can function properly with herbaceous vegetation and do not require woody riparian vegetation. Many (although not all) streams with less than 0.5 percent gradient, where the floodplain is saturated to the surface through most of the growing season, tend to be dominated by herbaceous vegetation at potential. In other cases, having woody vegetation present may be the desired condition but is not necessary for the reach to function properly. Streams greater than 0.5 percent gradient with cohesive substrates or bank materials may have the potential to produce both herbaceous and woody stabilizing vegetation but may only require herbaceous stabilizers to function properly. For example, if a reach contained Nebraska sedge and beaked sedge, the answer to item 6 would be "yes." If the same reach contained only Nebraska sedge, the answer to item 6 would be "no."

If it is determined that a reach needs woody vegetation for function, and is found to have (for example) peachleaf willow and coyote willow, the answer to item 6 would be "yes,"

as this is sufficient composition to recover or maintain this reach. If this same reach contained only coyote willow, the answer to item 6 would be “no.”

Some reaches may require both herbaceous and woody riparian vegetation to dissipate energy. These are often reaches with unconsolidated, medium to coarse substrate or bank material subject to high-energy flow events. Item 6 can be answered both “yes” and “no” if both herbaceous and woody vegetation are required but one is present and the other is not (e.g., Nebraska sedge and Baltic rush are present but willows needed for function are absent). If this is the case, sufficient rationale must be provided to clarify this situation.

Caution must be used when assessing reaches that lack a diversity of stabilizing species near the water’s edge. The presence of only one stabilizing species is not uncommon on streamside surfaces where the water table is shallow and stable. The ID team needs to understand the growth habits of the riparian plants on the reach. In general, areas where stable water tables occur near the surface result in limited species diversity. Mesic areas (moderately moist areas) that are further away from the stream, where the water table is somewhat deeper, tend to produce greater species diversity.

“NA” would apply for those stream types that do not require vegetation to function properly, for example, A stream types.

Supporting Science

Riparian vegetation is usually extremely heterogeneous as evidenced by many riparian classification documents. In general, ecosystem stability is characterized by an increase in species diversity, structural complexity, and organic matter (Kormondy 1969). Fluvial landform dynamics associated with natural systems appear to be inextricable from associated riparian plant species characteristics (Corenblit et al. 2009). Different landforms at the reach scale generally exhibit differences in available water for associated plant needs (Cooper and Merritt 2012). Monocultures don’t appear to be able to maintain fluvial landforms associated with natural stream dynamics in most cases. Monocultures are also susceptible to disease, herbivory, insect infestations, and extreme temperature fluctuations. Riparian communities must be able to adapt to extremes in water availability and stresses associated with anaerobic/aerobic conditions occurring in the rooting zone.

Climatic changes, including drought and wet cycles, continue to occur throughout the United States. However, the period between successive drought (or wet) years is completely unpredictable and variable. Streamflow and attendant water tables may vary considerably over time in conjunction with precipitation and runoff. Therefore, the diversity of stabilizing plant species within the riparian area must be enough to accommodate substantial shifts in the water table or zone of saturation or to sustain itself under varying conditions.

Although thresholds for diversity of stabilizing plant species are not firmly established, in most cases, stability reasonably would be expected with at least two stabilizing species present in the riparian area.

Correlation with Other Assessment Items

This item specifically addresses the presence of stabilizing species, while items 9 (stabilizing root masses present) and 11 (adequate stabilizing riparian vegetation) help determine if recognizable and distinct stabilizing plant communities have started to develop and if there is an adequate amount of stabilizing riparian vegetation. Although the focus of item 6 is on the stabilizing species needed to achieve a "yes" answer, the presence of pioneering/colonizing species, wetland indicator status of other species, and presence of invasive species or noxious weeds can also help in interpreting potential maintenance or recovery of the reach.

Item 7: There are adequate age classes of stabilizing riparian vegetation for recovery/maintenance

Purpose

For a riparian area to recover or maintain itself, it has to have vegetative recruitment of stabilizing species necessary for recovery or replacement. Item 7 addresses if the age classes that provide recruitment to maintain an area or to allow an area to recover are present (not whether all possible age classes are present).

Most woody riparian plant communities can recover or maintain themselves with two age classes, as long as one of the age classes is young (recruitment) and the other is middle-aged (replacement). The presence of current-year seedlings (germination) does not necessarily indicate recruitment (establishment of young plants) as there are many streams where germination is common and widespread but the plants have difficulty advancing into older age classes due to site-specific stream dynamics or other factors. Older age classes (mature) usually persist, as they are well connected to existing water tables, even with degraded conditions. Recruitment of herbaceous stabilizers is indicated by maintenance of dense sod where it exists, presence of young shoots around established plants in sparse communities, or apparent expansion of shoots into pioneering/colonizing riparian vegetation.

Observational Indicators and Examples

For riparian areas that require woody vegetation to achieve functionality, the ID team would answer "yes" if there are established sapling trees or young shrubs present on the reach being assessed. The ID team would answer "no" if either recruitment or replacement age classes are absent.

Many herbaceous stabilizers expand or colonize a site by rhizomes or stolons (e.g., Nebraska sedge). If there is a dense matting of these plants, the answer to item 7 would be "yes." If there are individual plants scattered along the reach being assessed, the answer to item 7 would be "no."

Many riparian areas have potential for both woody and herbaceous vegetation. If a combination of woody and herbaceous plants, either young or middle-aged, is present, the answer to item 7 would be "yes."

Item 7 also can be answered both "yes" and "no" if one class of vegetation (i.e., herbaceous stabilizers) appears to be reproducing well but the other (i.e., woody vegetation) appears to have limited or no recruitment. The rationale for both answers should be documented in the comments.

Because different vegetation functional groups and species are adapted to specific elevation surfaces across the riparian area (top of bank, floodplain, lower terrace, etc.), the recruitment of new plants of a particular group or species is tied to the moisture gradient and disturbance zones. For example, water sedge would not be expected on an upper terrace. Understanding this concept is important so that appropriate expectations are set for *where* to look for recruitment within the riparian area.

The ID team needs to recognize changes over time that affect potential for recruitment, especially in recovering streams. Willow species that require a depositional or erosional surface for germination and establishment may initially be recruited in a degraded E stream type, for example. The extent of exposed, aerated soils decline over time with recovery. Progression toward saturated, anaerobic conditions can decrease initial willow regeneration and favor sedge, rush, or other species adapted to anaerobic soils. Item 7 would still be answered "yes" in this situation even though willows are present but not recruiting. Again, the rationale for the answer should be noted on the form.

Judgment is required for plant communities that establish as even-aged stands as a result of episodic events, which is a common occurrence. Many woody species will establish in dense, even-aged stands where past disturbance has depleted or eliminated their presence and a change in management or climatic circumstances coincide for reestablishment. These stands may persist at an even age until disturbances open parts of them for additional recruitment. Episodic recruitment scenarios (such as postflood or postfire) or communities at potential natural condition may not have a diversity of age classes. Reaches that are in an advanced ecological status have limited opportunity for recruitment, but small patches of disturbance usually exist. These kinds of reaches would be given a "yes" response.

An "NA" answer would apply for channels that are entrenched and confined in bedrock (e.g., A1 stream types).

Supporting Science

Cooper and Merritt (2012) summarize methods to determine water needs of riparian vegetation, including plant recruitment, growth, and maintenance that can affect age class distribution. Recruitment is further affected by physiological and mechanical stresses such as defoliation, mechanical damage, and fire. The interrelationships of age structure can be quite complex, but general characterizations can be made of expanding, stable, and diminishing populations (Kormondy 1969) (figure 22). Expanding populations can generally be described by a pyramid shape of age class distribution,

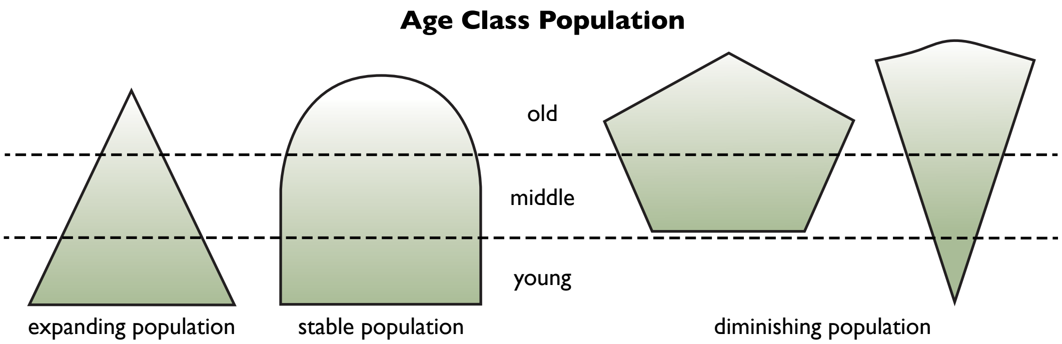


Figure 22. Age class population distribution shapes.

with many young plants forming a wide base, fewer middle-aged plants in the middle, and very few old plants at the top. Stable populations have more of a “bullet” shaped distribution, with rather equal numbers of young and middle-aged individuals forming the base and middle, and a gradually diminishing number of the oldest individuals at the top. Diminishing populations display more “urn” shaped distributions, with a narrow base of young plants that widens toward the older age classes, then often sharply narrows with the oldest individuals. Of particular concern are indicators of diminishing populations of bank-forming species/communities, such as low proportions or missing classes of young or middle-aged individuals where apparently suitable niches for recruitment are vacant.

For herbaceous species, the term age class distribution is somewhat misleading, but the intent to identify indicators of expanding, stable, or diminishing populations through recruitment/reproduction is the same. Dahl and Hyder (1977) discuss developmental morphology attributes that have implications pertinent to plant recruitment and maintenance. Indicators include the ratio of vegetative to reproductive culms (for plants reproducing by seed), amount and degree of lateral shoot development or tillering, and types of vegetative shoots.

Correlation with Other Assessment Items

Items 7 and 12 address recruitment, but item 12 is specific to systems that need woody material to function.

Item 8: Species present indicate maintenance of riparian soil-moisture characteristics

Purpose

Item 8 focuses solely on assessing the vegetation present to determine if soil moisture is being maintained (regardless of its other ecological/functional properties).

To answer item 8, the ID team looks for evidence that the level of the water table is being maintained or is moving towards its potential extent as indicated by the wetland indicator status of existing riparian vegetation. Maintenance or recovery of an existing water table is vital to the maintenance or recovery of a riparian area.

Riparian areas by definition are a transition between the aquatic and upland areas of a watershed, so care should be taken to evaluate the wet and dry vegetation components relative to appropriate positions on the landscape. An abandoned floodplain that is now a terrace cannot be expected to maintain the same riparian species it possessed as a floodplain.

Observational Indicators and Examples

To correctly assess the vegetation present for item 8, knowledge of riparian plant species is essential. The ID team must accurately identify specific plant species and should understand the nature of their occurrence on the landscape. Plants that primarily occur in wetlands are called hydrophytes. These plants need to be in contact with the water table, which is why they can be used as indicators of soil-moisture characteristics. The term hydrophytes is generally restricted to obligate wetland and facultative wetland plants. Plants are divided into categories relative to the likelihood of their occurrence in wetlands or nonwetlands (table 3) (Reed 1988, 1997). Individual plant ratings can be found on the National Wetlands Plant List (U.S. Army Corp of Engineers 2014).

Table 3. Wetland indicator status ratings based on ecological descriptions.

Indicator Status (Abbreviation)	Ecological Description (Lichvar And Minkin 2008)
Obligate (OBL)	Almost always is a hydrophyte, rarely in uplands.
Facultative Wetland (FACW)	Usually is a hydrophyte but occasionally found in uplands.
Facultative (FAC)	Commonly occurs as either a hydrophyte or nonhydrophyte.
Facultative Upland (FACU)	Occasionally is a hydrophyte but usually occurs in uplands.
Upland (UPL)	Rarely is a hydrophyte, almost always in uplands.

A "yes" answer would be given for item 8 when obligate wetland or facultative wetland plants are present on appropriate streambank and floodplain positions of a perennial reach as determined by expected wetland soil characteristics including depth and duration of plant-available water. Knowledge of individual species' soil-moisture requirements and tolerance is also required. A "no" answer would be given if facultative upland or obligate upland plants occupy positions expected to be occupied by hydrophytes (obligate and facultative wetland plants), indicating a possible change in flow-related variables.

Some intermittent and common perennial systems could be somewhat different, depending on flow-related characteristics, as their potential may be primarily facultative plants. If this is the case, and the riparian area is dominated by facultative plants, the answer to item 8 would be "yes." A riparian area along an intermittent or perennial stream with the potential for facultative vegetation would be given a "no" answer if the streambanks and floodplain were dominated by facultative upland or obligate upland plants.

Mature obligate and facultative wetland plants by themselves may not always indicate that soil-moisture characteristics are being maintained. When there is a long-term drop in the water table, the shallow-rooted vegetation will decline first, and there may be a composition change to more upland species. Mature plants that established contact with the water table long ago are often able to maintain contact with a declining water table for a long time due to deep roots. However, in the "flashy" systems of the southwestern United States, obligate and facultative wetland plant species recruitment is often in the active channel, and the floodplain potential is actually a combination of young or middle-aged and mature facultative wetland woody species interspersed with shallow-rooted facultative, facultative upland, or even obligate upland species depending on soils and drainage. In other instances, obligate and facultative wetland plants may occur well above the riparian area in nonhydric soils because they are connected to the riparian area by roots or rhizomes (e.g., Baltic rush).

Item 8 would be answered "NA" for riparian areas that have no potential to produce vegetation.

Supporting Science

Measurements of composition must be analyzed relative to soil, site, channel, and flow-related characteristics for quantitative analysis (Cooper and Merritt 2012). Recovering systems should be evaluated with care. Depositional events may initiate a temporary shift toward upland plants during the lag time required for a rising water table to "catch up." Such events should be noted so that the rating is appropriate and reflective of current conditions and trend.

A loss of soil moisture characteristics caused by a decline in ground water can initiate a shift from riparian plants to more upland plants if (1) the water level drops below the root zone, and (2) the duration of drawdown is long enough that riparian vegetation becomes stressed or experiences mortality. Short-term declines in ground-water levels (3-4 months) will generally only affect some very young plants or species that are particularly sensitive to water level declines; most of the time, a short-term decline won't stress vegetation enough to trigger a significant change in species composition (Paul Summers, pers. comm.). Myers (1989) and most of the classification literature mentioned under item 9 cite an increase in upland plants as an indicator of a declining water table.

Correlation with Other Assessment Items

Item 8 correlates with item 4 (riparian area is expanding). The expansion of obligate and facultative wetland plants may be an indication of a rising water table or reconnection with the floodplain.

Item 9: Stabilizing plant communities capable of withstanding moderately high streamflow events are present along the streambank

Purpose

Item 9 focuses on whether *streambanks* have stabilizing plant communities present along the reach to support recovery and maintenance. Streambanks with vegetation lacking extensive root masses are undercut during high-flow events and collapse. Excessive collapse of streambanks results in an increase of the channel's width/depth ratio, which reduces a riparian area's ability to dissipate energy. Gradient and sinuosity may also be adversely affected, further increasing stream energy.

Whereas item 6 is designed to determine if stabilizing species are simply present in the entire riparian area, this item is asking if those plants have formed *recognizable and distinct communities on the streambanks.* However, item 9 does not address adequacy and is not intended to determine if *enough* vegetation or *enough* communities are present.

Most stabilizing riparian plant communities are dominated by specific obligate and facultative wetland plants that have deep, strong root masses capable of withstanding high-flow events. In some geographic areas, some facultative plants may also function as stabilizers. Most plant communities dominated by facultative upland and upland species do not have stabilizing root characteristics. The presence of stabilizing plant communities, even if they do not dominate the streambanks along the reach, has additional interpretive value for recovery or maintenance potential of a reach over the presence of stabilizing species alone.

Observational Indicators and Examples

Riparian species, such as willow, alder, aspen, birch, and cottonwood, or deep-rooted herbaceous species, such as sedges, rushes, bulrush, and some riparian grasses, have root masses capable of withstanding moderately high-flow events (figure 23). If these plants have formed recognizable communities along a streambank or developing banks (such as point bars) of a degraded stream, the answer to item 9 would be "yes." For some intermittent systems (and some perennial systems as noted above), the presence of recognizable communities of facultative plants may be all that is required for a "yes" answer, as this may be all these systems can produce.

Figure 23. Stabilizing vegetation exhibits highly developed root structures.

A "yes" response is possible on item 9 if there are well-developed patches along the streambank that contain deep-rooted plant communities. In such conditions, it is likely that reproduction of additional deep-rooted vegetation could occur and eventually fill in the gaps along the streambank. If deep-rooted riparian plants only occur as scattered individual plants along a reach, item 9 would be answered "no."

Plant communities such as Kentucky bluegrass, redtop, blue grama, and sagebrush do not have root masses capable of withstanding high-flow events. If these communities exist *in lieu of* communities of stabilizing riparian plants on the streambanks, the answer to item 9 would be "no."

There are exceptions, such as high-gradient, bedrock, or boulder/cobble stream types, where the vegetation community contributes little, if any, to bank stability. For these stream types, the answer for item 9 would be "NA."

Supporting Science

Stability ratings have been developed for plant communities and individual plant species and other bank features (barren areas, rock, woody material) that help characterize how well the streambanks may resist erosion (Winward 2000; Burton et al. 2011; Crowe and Clausnitzer 1997). Many obligate and facultative wetland species, and some facultative species, have high erosion control potential.

Erosion control potential can also be determined from rooting habits of individual species (Lewis 1958; Manning et al. 1989; Kleinfelder et al. 1992) or preferably from ratings or discussions of both species and plant communities, such as in Weixelman et al. (1996), Hansen et al. (1995), Manning and Padgett (1995), USDA Forest Service (1992), and Kovalchik (1987). Even though these publications are geographically specific, the species and similar plant communities occur broadly across various geographic regions.

Correlation with Other Assessment Items

This item correlates with item 11 (adequate stabilizing riparian vegetation) and is particularly useful for cases where item 11 is answered "no." In those instances, a "yes" on item 9 indicates that the streambanks have an adequate source of the right kinds of plant communities to support recovery and progress towards an adequate amount of stabilizing vegetation if provided an opportunity to do so.

Item 10: Riparian plants exhibit high vigor

Purpose

Item 10 refers to whether riparian plants are healthy and robust or are weakened and stressed. Plants that are in an unhealthy state have a diminished ability to grow (expand), reproduce, or contribute to function and can be at risk of mortality. The loss of key riparian plants can subject the riparian area to impairment. The aboveground expression is a reflection of belowground condition and the ability of riparian species to stabilize an area.

Observational Indicators and Examples

Reduced height, root growth, leaf width, leaf area (production), and signs of stress, such as chlorosis, have traditionally been used as indicators of reduced vigor on herbaceous species. Growth form (morphology), leader length, and the amount of dead or dying limbs (Cole 1958; Keigley and Frisina 1998) are also longstanding indicators of shrub vigor. However, dead and dying limbs are common in willows with a cyclic life history. Clump willows like Geyer willow, Lemmon's willow, and Booth's willow are examples of species that replace their limbs approximately every 20 years. The dead limbs remain to protect the new shoots that emerge from the base (Wayne Elmore, pers. comm.).

Chlorosis occurs when leaves produce insufficient chlorophyll. If willow leaves are turning yellow during the growing season, often water is being removed or added to a system, which stresses the plants. However, change in color can also indicate a disease, nutrient problem, or climatic factors.

Woody plants should be separated from herbaceous plants when assessing vigor. For most riparian areas, plant size, shape, and leaf color during the growing season can be used to discern vigor. For example, if willows in a given reach are well rounded and robust, the answer to item 10 would be "yes." If these same plants have altered growth forms (for example, they are hedged/highlined) or have suppressed leader growth (figure 24), the answer to item 10 would be "no."

The abundance of herbaceous plants, in conjunction with other indicators such as leaf width or height, can be used to assess vigor. For example, if Nebraska sedge occurs as a dense mat with adequate leaf width on the reach being assessed, the answer to item 10 would be "yes." If Nebraska sedge occurs as narrow-leafed, isolated plants, or broken clumps that are not forming communities (interspaces between sedge plants are occupied by upland species or bare ground), the answer to item 10 would be "no." In

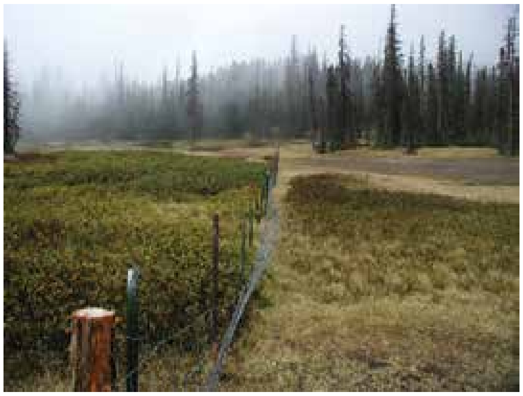


Figure 24. Shrubs to the left of the fence line show high vigor whereas those to the right of the fence line do not. Neither side was grazed during the season when the photo was taken. The shrubs on the left have a much higher density and more robust leaf structure.

some instances, narrow-leafed plants may be healthy but young and in the process of expanding by rhizomes from more robust individuals or patches.

This item can also be answered both "yes" and "no" if, for example, herbaceous species appear healthy and vigorous and woody species appear diseased or stressed. For riparian areas that have no potential to produce vegetation, this item would be answered "NA."

Supporting Science

The relative health of plants within a community can be expressed in many morphological and physiological forms. The reproductive indicators for herbaceous species discussed under item 7 (unhealthy plants do not reproduce as well) and plant size, leaf area and size, and root growth are all associated with relative plant health or vigor.

When healthy and vigorous, some stabilizing riparian plant communities have up to a 3:1 ratio of belowground to aboveground growth, whereas upland plant communities are closer to a 1:1.5 ratio (Dwire et al. 2004).

Weixelman et al. (1996) have established procedures for documenting mean rooting depth and expected ranges of rooting depth associated with various ecological conditions of specific herbaceous riparian plant communities. Shallower rooting depths associated with declining status can be, in part, a quantitative measure of the vigor of the community.

Declines in ground water can cause plants to appear weakened and stressed. However, riparian vegetation that exhibits low vigor or appears stressed is not always a reliable early-warning indicator of declining ground-water levels. Other factors, such as disease, drought, or temperature extremes, can also influence vigor. The most reliable approach for detecting changes in shallow ground-water conditions is to combine a detailed assessment of riparian vegetation composition and vigor with monitoring of ground-water levels in wells.

Correlation with Other Assessment Items

There is a correlation between items 10 and 7 (recruitment of stabilizing riparian vegetation). If there is a "no" response on item 7, a "no" response is likely on item 10, depending upon the reason for the lack of age classes. This item also correlates to item 8, in that a drop in the water table would result in a decrease in vigor prior to an actual shift in species composition.

Item 11: Adequate amount of stabilizing riparian vegetation is present to protect banks and dissipate energy during moderately high flows

Purpose

Item 11 pertains to whether there is an adequate *amount* of vegetative cover, as expressed by the lineal distribution of stabilizing riparian plant communities present along the streambank, to dissipate and withstand stream energies from moderately high flow events (i.e., 5-, 10-, and 25-year events).

This item is important for areas where vegetation is required for proper functioning condition. For a riparian area to recover, composition of the right plant communities, vigor, and recruitment are necessary, but until an adequate amount of vegetation is present, the riparian area is vulnerable.

Item 11 addresses the amount of cover, while items 6-10 address species, recruitment, wetland indicator status, the presence and location of communities, and vigor—not the amount of cover.

Observational Indicators and Examples

Although there are exceptions, most perennial stream channels require at least 70 percent total lineal stabilizing cover (vegetation, large or anchored rock, anchored wood) on the streambanks to buffer the erosive force of water. Depending on the size and composition of soil materials on the banks, 80 percent total lineal cover or more may be required for some streams, and many low-gradient, sinuous streams require as much as 90 percent or more total lineal cover to maintain function. Local references and effectiveness monitoring, if available, should be used to determine minimum cover requirements. Anchored rock and anchored wood constitute significant portions of the streambanks on some reaches; if this is the case, the combined cover of stabilizing vegetation, anchored rock, and anchored woody material should be considered in the estimate of adequate cover (Winward 2000).

If a streambank for the reach being assessed has the potential to be dominated by riparian plants but is dominated by upland plant communities, the answer to item 11 would be "no." If this same streambank has 50 percent stabilizing riparian plant communities and 50 percent upland plant communities, the answer to item 11 would still be "no" because, in general, it requires at least 70 percent stabilizing riparian vegetation.

Many intermittent and some perennial systems may not have the potential for obligate and facultative wetland stabilizing plant communities and have facultative plant communities that stabilize streambanks.

Item 11 would be answered "NA" for riparian areas that do not need vegetation to achieve PFC.

Supporting Science

As indicated, stability ratings have been developed for plant communities and individual plant species and other bank features (barren areas, rock, woody material) that help characterize how well the streambanks may resist erosion (Winward 2000; Burton et al. 2011; Crowe and Clausnitzer 1997). Because stream channels are dynamic systems subject to constant energy and disturbance, 80-90 percent total lineal cover of stabilizing vegetation, anchored rocks, and anchored wood on the streambank may be all that is expected for most streams at potential; few may achieve 98 percent cover or more (Winward 2000). Adequate stabilizing vegetation combined with anchored rocks/logs is usually, if not always, less than the potential.

Winward (2000) and Burton et al. (2011) both provide total vegetation cover and vegetation stability class metrics derived from greenline vegetation data. Stability class values of 7 and above (on a scale with 1 being lowest and 10 being highest) are considered high to excellent by Winward, while values of greater than 6 are considered high (the highest class in a scale of low, medium, and high) by Burton et al. (2011) (table 4). High stability class values calculated by either method are generally considered adequate for PFC. From a practical assessment standpoint, greater than 70 percent estimated stabilizing cover will usually yield a high stability rating. Practitioners may use a higher value for particularly sensitive stream types or a lower value for resistant stream types if rationale is provided. Although there is no detailed research to validate how much cover different stream types need to maintain function, a great amount of empirical evidence encompassing thousands of stream miles assessed by PFC developers and practitioners over more than 20 years suggests that 70 percent is a reasonable minimum stabilizing cover necessary for function absent site-specific information.

Table 4. Relative values based on general rooting characteristics assigned by Burton et al. (2011); numerical values conform to Winward (2000).

Forbs	
Taproot or most roots, shallow (<15 cm)	Low (2)
Fibrous roots, usually up to 30 cm	Medium (5)
Rhizomatous roots, with 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, cespitose, tufted, or short 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 (<15 cm)	Medium (5)
Root crown with spreading roots	High (8.5)
Widespread root systems	High (8.5)

Bank erosion occurs when the eroding force (shear force) of water moving along the bank exceeds those resisting forces (inertia, friction) in the bank. Shear force on the bank is directly proportional to the velocity gradient in the water (i.e., the rate at which velocity increases when moving away from the bank). Thus, if the velocity gradient in the near-bank region is steep, the shear stress is high. Conversely, if the velocity gradient in the near-bank region is low, shear stress on the bank will be low.

Forces resisting bank erosion result from physical properties of the streambank and protection from erosive shear by overhanging vegetation. Physical properties of the bank are primarily related to cohesive strength of bank materials and other factors increasing bank tensile strength. Cohesive strength of bank materials is largely a function of soil texture (especially particle size), soil chemistry, and soil structure. Vegetation root mass, depth, and strength are important factors in increasing tensile strength of the bank.

Vegetation has the potential to influence the balance of energy during moderately high flows in at least two ways. First, living or dead vegetation (or any other cover, for that matter) that extends into the flow has the potential to reduce near-bank velocities, thus reducing erosive shear forces acting upon the bank. In an ideal situation, vegetation along the bank is sufficient to produce a zone of near-zero velocities near the bank, effectively moving the velocity profile away from the bank so that shear stress is dissipated in turbulent eddies in the flow. A similar process occurs in the overbank region when density of vegetation is sufficient to produce reduced velocities at ground level in overbank flow during flood events.

Vegetation also influences the balance of energy during moderately high flows by increasing resisting forces in the streambank. Particularly in noncohesive soils and sediments, the presence of stabilizing vegetation may greatly increase binding forces in bank materials. Tensile strength provided by root masses of riparian vegetation may be the primary source of resistance in alluvial soils. Tensile strength will be dependent upon both the kind of vegetation present and the extent and density of root masses. Determination of root structure adequacy will be site-specific, as less cohesive sediments will require greater root structure to achieve the same level of stability as more cohesive sediments elsewhere.

Correlation with Other Assessment Items

The cause of streambank instability is closely related to the channel geometry described in item 1 (floodplain frequently inundated), item 3 (sinuosity, gradient, and width/depth ratio in balance), and item 15 (streambanks laterally stable). A lack of appropriate channel geometry (lack of floodplain access and channel dimensions and pattern not conducive to energy dissipation), *combined* with a lack of stabilizing riparian plants on the streambanks, contributes to bank instability.

Items 6-9 can all have "yes" responses with item 11 having a "no" response if there is simply not enough stabilizing cover on the streambanks. Conversely, if items 6-9 all have "no" responses, it is not possible for item 11 to be answered "yes." Item 15 (streambanks laterally stable) is also related to item 11 as inadequate streambank cover and bank instability can contribute to excessive lateral channel movement. In addition, items 4 (riparian area expanding) and 14 (point bars revegetating) are determined by evaluating the presence of adequate riparian vegetation on the streambanks.

Item 12: Plant communities are an adequate source of woody material for maintenance/recovery

Purpose

Item 12 refers to the amount of live trees present to become a source of downed woody material for stream maintenance or recovery. *Before answering item 12, the ID team must determine if woody material is necessary for a given reach to function properly and if the woody material present is large enough to stay for an adequate time to function as a hydrologic modifier.* Material size will vary by stream size, flow regime, and ecological setting, therefore each site should be evaluated to determine what is appropriate and where woody material is required. Many rangeland and meadow riparian areas do not require woody material to maintain channel stability.

Some stream systems cannot maintain their dimension, pattern, and profile and function properly without woody material, including small limbs and root wads. These streams require a supply of woody material on the banks and floodplains, over time, that is of the appropriate size to capture bedload, aid floodplain development, provide organic matter, and dissipate energy.

The size of downed wood provided by species like aspen or water birch may provide adequate hydrologic control on some smaller streams, while mature cottonwoods, Douglas firs, or similar trees may be required for larger systems.

Observational Indicators and Examples

If woody material is necessary and live trees are present, the ID team must determine if they are sufficient in number, age, and size. If a reach contains an adequate number of mature trees and they are large enough to serve as hydrologic modifiers, the answer to item 12 would be "yes."

If a stream reach requires woody material and there are young trees but no living mature trees present that will access the stream in the future, then the answer to item 12 would be "no" but with a comment describing the current situation. If there are only a few scattered or isolated trees, the answer to item 12 would also be "no." Although standing dead trees can be a source of woody material, for maintainance and recovery, the reach needs to have an adequate source of live trees.

This item will be answered "NA" for many low-gradient riparian areas such as herbaceous meadows because downed wood is not needed for stability.

Supporting Science

A large amount of recent literature documents observations and measurements of forested riparian areas and describes the relative amount of woody material needed to maintain stream geomorphology and function (Gregory et al. 2003; Naiman et al. 2002). Some forested riparian areas depend on downed trees to maintain or achieve desired condition and achieve potential (Latterell and Naiman 2007). The way each part of the stream system functions can change as streams merge and increase in size. These changes result in an enormous variety in stream slope, geology, hydrologic regimes, and vegetation types, which increases the importance of judging each reach against its potential (Chin et al. 2008).

Dead, down, and live trees are essential to the development and maintenance of some forested riparian stream ecosystems, from their headwaters to the downstream end of the forest stream continuum. A riparian/stream continuum is in a state of dynamic stability when it is functioning properly and the movement of woody material down the stream system is normal and necessary. The function of woody material in the stream and on the floodplain changes from the headwaters to the wider downstream valleys.

Woody material is deposited through floods, fires, windthrow, torrents, landslides, and normal tree mortality. These events are essential to maintaining and restoring the riparian stream system's functionality. The spatial location of woody material is continually shifting during annual and episodic events. This spatial movement replenishes materials that are broken down or flushed out of the system. The temporal processes of the forest riparian/stream system should be measured in decades and centuries.

Correlation with Other Assessment Items

Item 12 closely relates to item 13 (floodplain and channel characteristics adequate to dissipate energy) because item 12 addresses the adequacy of the source of woody material important for energy dissipation on the floodplain and in the channel.

7. Assessing Geomorphology Attributes and Processes

Items 13-17 deal with erosional and depositional attributes and processes that have to be in working order for a stream channel and riparian area to function properly. The intent of items 13-17 is to address observations of fluvial geomorphology, sediment load, discharge, and stream energy and to evaluate their effects on stream processes and riparian conditions. Key concepts in one or more of these items include:

- The balance between driving and resisting forces.
- The balance between sediment supply and transport capacity.
- The mechanism by which energy is dissipated within a channel or across a floodplain.
- The relationships between watershed runoff and stream discharge.
- The distinctions between rates and magnitudes of natural processes in comparison to those that result from human management of riparian areas, specifically, and of watersheds as a whole.
- Internal and external factors that can push unstable systems across a geomorphic threshold, leading to rapid and substantial changes in channel dimension, pattern, and profile.

An objective of the PFC assessment method is to determine if stream channels and connected riparian areas are stable. Stability is the capacity of the stream channel to maintain dimension, pattern, and profile during moderately high flow events (i.e., stream discharges of 2-, 5-, 10-, and 25-year recurrence intervals). Rare, high-magnitude, low-frequency events (such as floods with a recurrence interval greater than 25 years) can destabilize channels and reconfigure valley bottoms, even if the riparian area was in PFC prior to the flood.

Stability does not imply a rigid or static condition. Instead, stability is meant to describe a resilient, flexible condition synonymous with the concept of a graded stream. Mackin (1948) described the graded stream as "one in which, over a period of years, slope is delicately adjusted to provide, with available discharge and with prevailing channel characteristics, just the velocity required for the transportation of the load supplied from the drainage basin. The graded stream is a system in equilibrium."

The graded stream is one where adjustments occur, over time, in channel slope, but only to a minor extent, or not at all, by concurrent changes in channel dimensions.

The relative stability of a channel can also be illustrated by the Lane equation:

$$Q_s d \; \alpha \; Q_w S$$

which states that the product of the sediment load (Q_s) and particle diameter (d) is proportional to the product of stream discharge (Q_w) and stream slope (S). The Lane/Borland balance (Pemberton and Strand 2005) is a conceptual graphic model of the

Lane equation (figure 25). It portrays processes of aggradation (deposition and elevation of the channel bed) and degradation (channel incision) in terms of sediment supply (sediment load and size) and transport capacity, discharge, and gradient (stream slope). The concepts inherent in the Lane equation and Lane/Borland balance can facilitate discussion of stream function; however, other stream and riparian attributes indicative of broader riparian functionality, such as bed and bank roughness, channel dimensions, floodplain accessibility, and stabilizing riparian vegetation, are not explicitly portrayed or accounted for by this model.

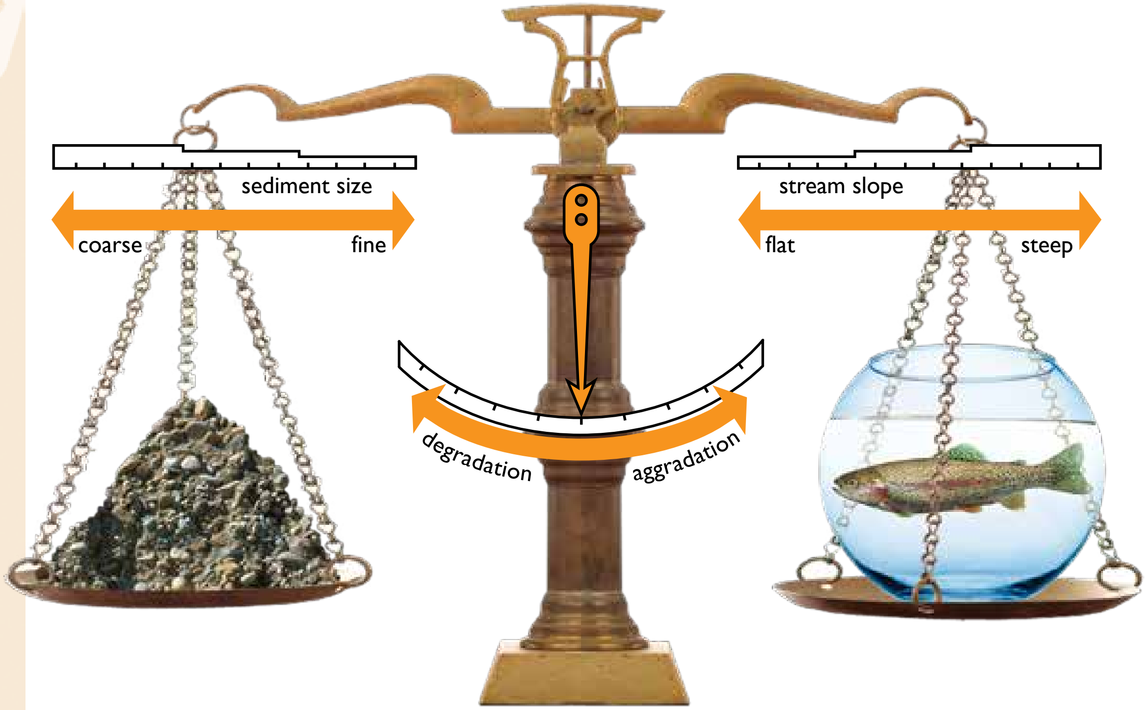


Figure 25. Lane/Borland balance is a conceptual model that portrays processes of aggradation (deposition and elevation of the channel bed) and degradation (channel incision) in terms of changes in sediment supply, sediment size, discharge, and gradient. Adapted from the original illustration by James Vitaliano, Bureau of Reclamation (Pemberton and Strand 2005).

Items 13-17 on the assessment form address geomorphic attributes and processes:

- Item 13 deals with the dissipation of energy within the channel and on the floodplain. Energy dissipation is vital to maintaining riparian resilience and channel stability. In the presence of excessive unchecked energy, driving forces exceed resisting forces. The fluvial system may become unstable and cross a geomorphic threshold, and the channel may incise or widen. When resisting forces exceed driving forces, transport capacity diminishes and the stream channel form will adjust to compensate for an inability to transport its sediment load.
- Item 14 focuses attention on the condition of point bars. Point bars form within the active channel on the inside bend of a meander where stream hydraulics deposit bedload sediment. When the fluvial/riparian system is operating properly, riparian vegetation on the top of the point bars will slow stream velocity, induce

deposition, and create a hydraulic connection between the top of the point bar and the floodplain. Improper riparian management may prevent riparian vegetation from colonizing and stabilizing the top of the point bar and maintaining hydraulic connectivity with the floodplain.

- Items 15 and 16 are directed at the lateral and vertical stability, respectively, of the channels. Alluvial channels are not static; they naturally migrate across their valley floors. However, the highest rates of channel migration should occur at meanders, where cutbank erosion acts on the outside bend of a meander. Rapid thalweg relocation, unusual channel avulsion, excessive streambank erosion, or cutbank erosion in excess of point-bar deposition all suggest excessive energy and erosion in the system. Likewise, channels that incise or widen so that floodplains are no longer accessible during high-flow events are unstable and cease to function properly.
- Item 17 integrates the observations throughout a drainage basin to determine if the sediment supply and transport capacity are in balance.

Stream systems are dynamic environments where incremental changes occur over time with nearly every change in discharge. However, a properly functioning stream system will maintain a stable, resilient form (i.e., combination of channel dimensions, pattern, and profile) throughout incremental changes in discharge. A poorly functioning stream/riparian system may cross a geomorphic threshold and undergo rapid and substantive changes that can only recover or be restored through a great expenditure of resources or over a long time. Such transformed streams undergo a cycle of channel evolution (figure 7), which can take place over decades or take hundreds of years.

Item 13: Floodplain and channel characteristics (i.e., rocks, woody material, vegetation, floodplain size, overflow channels) are adequate to dissipate energy

Purpose

For riparian areas to function properly and maintain equilibrium, energy has to be dissipated during high-flow events. Item 13 focuses on the listed attributes and processes that provide roughness and dissipate energy appropriate for the landform setting and the potential of a reach. On some stream types, energy is dissipated when an adequately sized floodplain is accessed and moderately high flows can spread out, channel characteristics create forces resistant to downstream movement of channel and bank materials, or obstructions to flow, such as large rocks, woody material, or vegetation, slow water velocity. If these energy-dissipating elements are removed from a stream reach, water velocity during floods would increase, which could cause excessive erosion. In most alluvial systems, both channel characteristics and an adequate floodplain are needed to effectively dissipate energy. In landform-controlled systems, proper function is possible without floodplains.

Observational Indicators and Examples

The ID team determines whether the specified floodplain and channel characteristics are a part of the stream type being assessed, and if they are, the ID team observes whether they are in place and adequately dissipating energy. Determining the discharge associated with the 5-, 10-, and 25-year flow events for the reach being assessed will help the ID team interpret this item. In many cases, if energy is being dissipated adequately, then floodplain and channel characteristics are sufficiently resistant to limit erosion to short, discontinuous patches.

Indicators of energy dissipation include:

- **Rocks:** Rocks can influence the channel cross section and stream type. Anchored rocks that seldom move during high flows provide stability. Large rocks that are exposed during high-flow events also provide resistance and slow water velocity. The ID team should note if rocks are necessary or playing a role in energy dissipation based on the geology and potential of the reach being assessed.
- **Woody material:** Riparian areas that require anchored wood, downed logs, downed branches, or jams to function are forested, high energy, or large bedload environments where the woody material is required to capture sediment and bedload for streambank repair and floodplain development. Woody material can vary from a few pieces of wood with associated organic material to several dozen large logs tangled together spanning a stream channel. For areas that require woody material to dissipate energy, the answer would be "yes" if woody material is in place and some of it is large enough to remain in place during high-flow events. The answer would be "no" if the area lacks woody material to act as hydrologic modifiers.
- **Vegetation:** Live vegetation that is an obstruction to flow also provides roughness. Note that vegetation does not always grow in a channel because it can be repeatedly removed by high flows. The ID team should note if vegetation is necessary or playing a role in energy dissipation based on the potential of the reach being assessed.
- **Adequate floodplain size:** Channels that are progressing through a channel evolution sequence similar to the example in figure 7 are, in most cases, able to adequately dissipate energy only after the floodplain has developed the appropriate width. Indicators that this widening has occurred include:
    - A vegetated slope developed at the base of the terrace walls or vertical walls made up of highly cohesive soils that are no longer eroding.
    - Maintenance of stable channel dimensions during and after moderate floods.
    - Formation of appropriate meander-width ratios (belt width divided by bankfull width). Rosgen (1996) presents average values and ranges for meander-width ratios by stream type. The ranges are large, so other indicators, such as sediment processing and whether riparian vegetation can establish, thrive, and recover come into play for interpretation.
- **Overflow channels:** Some single-thread stream reaches have backwater areas, abandoned meanders (oxbow lakes), or overflow channels that are accessed during floods and contribute to energy dissipation. These reaches are different from naturally braided or anastomosing channels. Abandoned meanders and overflow

channels are usually only connected to the main channel during floodflow events. The presence and condition of riparian vegetation or woody material in or near overflow channels influences energy dissipation as well (figure 26). The presence of stable overflow channels would contribute towards a "yes" answer for this item. If overflow channels have been artificially disconnected from the main channel and the main channel shows signs of excessive erosion, the answer would be "no."

Figure 26. Overflow channel (A) adjacent to the stream (B). The overflow channel is providing for energy dissipation from both its position on the floodplain and the roughness contributed from the adjacent riparian vegetation.

Item 13 will never be answered "NA"; it will always have either a "yes" or "no" answer.

Supporting Science

One of the three governing laws of fluid mechanics is that total energy (i.e., potential energy due to height above some elevation point, kinetic energy due to velocity of flow, and pressure energy due to depth of flow) should be conserved as water moves downstream through a channel. However, even in the case of uniform flow, where both velocity and depth are unchanged in the downstream direction, potential energy is lost as water moves from a higher position to a lower one. This energy loss is a result of friction/shear stress at the channel boundary. Various hydraulic equations have been developed to quantify this energy loss and to predict the stable depth of flow for a specified discharge in a channel.

Although item 13 focuses on a subset of what provides roughness and resistance to flow, the supporting science comes from Manning's equation, which provides the basis for computing differences in flow velocities due to differences in hydraulic roughness (Arcement and Schneider 1989). Manning's roughness coefficient *"n"* may be thought of as an index of the features of hydraulic roughness that contribute to the dissipation of stream energy. It varies with changes in stage (water level), channel irregularities, obstructions, vegetation, sinuosity, bed material, and bedforms. Cowan (1956) developed a formula for estimating *"n"* values based on observed channel characteristics. Chow (1959) published suggested values for *"n"* for natural streams tabulated according to factors that affect roughness, ranging from 0.020 to 0.200. Barnes (1967) catalogued verified *"n"* values for 50 stream channels having roughness coefficients ranging from 0.024 to 0.097 and presented channel data, plan sketches, cross sections, and photographs to increase familiarity with the appearance of typical channels with known roughness coefficients.

In forested areas, woody material contributes to energy dissipation that supports riparian function by adding to flow resistance, increasing sediment storage, reducing sediment transport, and influencing channel form. The characteristics and function of woody material change in relation to stream size (Bilby and Ward 1989; Gurnell et al. 2002; Naiman et al. 2002). Braudrick and Grant (2000) found that large-diameter pieces that are oriented parallel to flow and rootwads increased the stability of woody material.

Correlation with Other Assessment Items

Item 13 is related to item 1 (floodplain frequently inundated). For some stream types, floodplain access is very important for energy dissipation. Where a floodplain may be developing but is not yet adequate in size, item 1 would be answered “yes” but item 13 would be answered “no,” with appropriate remarks describing the situation. If item 1 is answered “no” and no new floodplain has developed, then item 13 would also be answered “no.”

Item 13 is also related to item 12 (adequate source of woody material). Item 12 addresses trees that will fall over and become woody material, while item 13 addresses the woody material that is already in the floodplain or channel. Item 17 (stream in balance with water and sediment supplied) is related because floodplain and channel characteristics that are adequate to dissipate energy will have a positive influence on the sediment/water balance.

Item 14: Point bars are revegetating with stabilizing riparian plants

Purpose

Item 14 pertains to whether stabilizing riparian vegetation is establishing on the top of point bars to capture sediment and aid in floodplain development and to maintain a balance between bank erosion on the cutbank and bank formation on the point bar.

Formation and extension of point bars is a natural depositional process for some alluvial streams. Riparian vegetation must colonize the point bar to (1) stabilize and prevent excessive point-bar erosion, (2) trap sediment during high-flow events, (3) aid in floodplain development, and (4) improve water quality by capturing sediment from stream water. When vegetation fails to establish on the tops of point bars, the energy associated with high-flow events can cause erosion that affects sinuosity, gradient, channel dimensions, and floodplain accessibility, which results in impairment of riparian function. For example, in figure 27, the point bar located on the right side of the channel has largely been removed by a recent flow event, which overwidened the channel.

Figure 27. Erosion of point bars may result from excess velocity, related in part to channel incision or lack of roughness characteristics. Erosion of point bars can lead to overwidening of the channel, a decrease in floodplain accessibility, a decrease in sinuosity, and a corresponding increase in channel gradient.

Observational Indicators and Examples

A geomorphically stable point bar commonly exhibits the characteristics shown in figure 28:

- A cross-sectional shape, with a gently inclined to moderately convex profile across the point-bar deposits from the floodplain toward the thalweg.
- Topographic continuity (and hydrologic accessibility) between the top of the point bar and the floodplain.
- A fining-upward sequence of sediment, (i.e., the deposits at the base of the point bar are generally the coarsest with progressively finer sediment toward the top of the point bar).
- Preservation of the channel cross-sectional area, indicating that the volume of sediment deposited on the point bar (as suggested by growth of the point bar from time 1 (t_1) through time 4 (t_4)) is approximately equal to the volume of sediment eroded from the corresponding cutbank (suggested by retreat of the cutbank from t_1 to t_4) on the opposite side of the channel.
- Establishment of stabilizing riparian vegetation near the top of the point bar, commonly with pioneering/colonizing riparian vegetation lower on the point-bar surface.

Point bars are an important characteristic of most meandering streams, especially C stream types and some B stream types. Also, point bars can occur in some F stream types, particularly where these entrenched stream types have begun to widen and form inset floodplain features as part of a channel evolutionary path toward more stable stream types. Observations concerning the presence of point bars and establishment of riparian vegetation on point bars in F stream types provide important information on restoration potential and stage of channel recovery.

E stream types typically do not have point bars. The situations where point bars are observed in E stream types should be carefully noted and studied. These occurrences might represent transitory situations where E stream types are degrading into C stream types or vice versa.

Point bars are not expected in landform-controlled streams with high gradients and narrow valley bottoms. Such streams (A stream types) dissipate energy primarily through bed-roughness elements, cascades, and step pools. The answer to item 14 in steep, straight, landform-controlled channels is "NA."

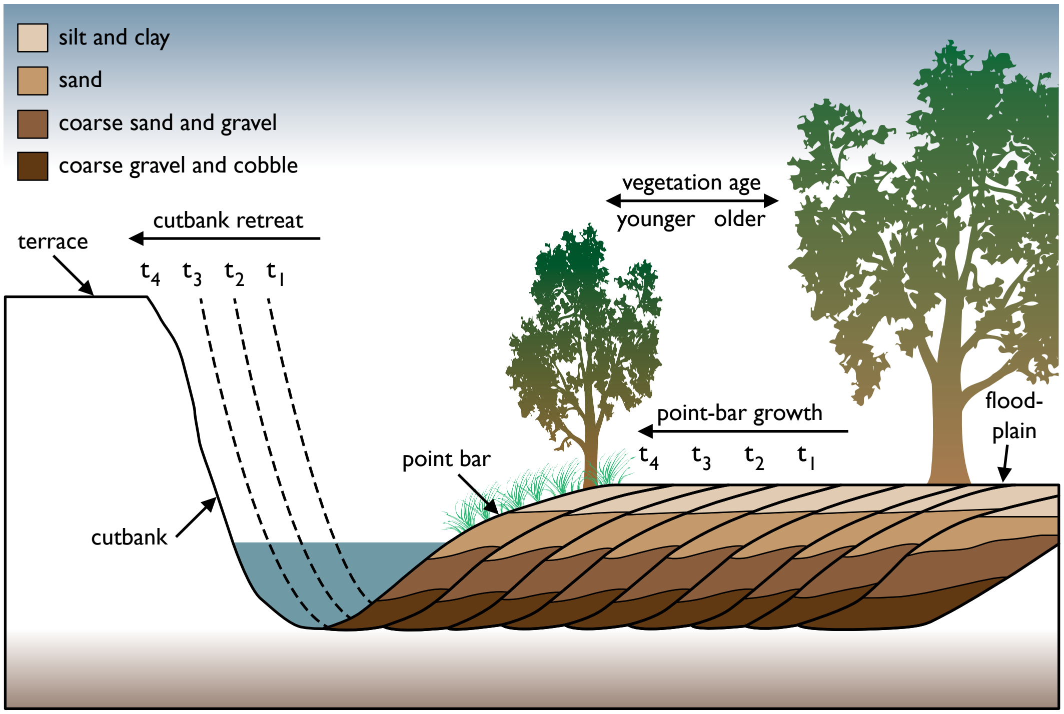


Figure 28. An idealized cross section through a point bar of a hypothetical meandering channel illustrates (1) gently sloping to convex upward form of the point-bar surface; (2) topographic continuity between the top of the point bar and the floodplain; (3) fining-upward sequence of sedimentary textures within the point bar; and (4) a constancy of channel cross-sectional area, indicating that the volume of erosion on the cutbank is approximately equal to the corresponding volume of sediment accumulated on the point bar over time (as suggested by channel position from time 1 (t_1) through time 4 (t_4)).

If point bars are expected for the stream type but are not developed due to low sinuosity, higher than expected gradient, or in-channel erosion that has removed point bars, then the answer to item 14 would be "no." This situation occurs when C stream types are destabilized and are converted into D streams by excess sediment load or into F or G stream types by excess energy that widens or incises the channel.

If the top of a point bar is vegetated with obligate upland or facultative upland plants, the answer to item 14 could be "yes" if the reach is part of an intermittent system with a limited potential for hydric riparian plants. The answer could be "no" if the reach is perennial and the potential vegetation should be dominated by obligate wetland and facultative wetland plants.

If point bars are vegetated by stabilizing riparian plants like willows and sedges, the answer to item 14 would be "yes." Point bars are dynamic features within a channel. Consequently, this item is focused on the presence or absence of stabilizing riparian species at the top of the point bar (near the floodplain) and is not intended to determine if there is enough of this type of vegetation, which is the intent of item 11.

The establishment of stabilizing vegetation on point bars reflects the interplay among stream energy, sediment load, hydrologic regime, and riparian vegetation. For example, in a high-energy system, stabilizing riparian plants will likely be located high on the point bar; lower parts of the point bar are part of the active channel and could be below a distinct scour line (figures 29 and 30). Also, where the hydrologic regime has a high range between peak and base flows, stabilizing riparian vegetation would be expected near the top of the point bar, whereas annual plants or pioneering/colonizing riparian vegetation might establish near the base of the point bar near the low- or base-flow waterline. However, the colonizing plants are well within the active channel and may be removed during the next high-flow event. There may be unvegetated portions of the point bar between the stabilizing vegetation near the top of the point bar and the colonizing vegetation at the base of the point bar. Finally, the upstream end of a point bar generally experiences higher energy than the downstream end. Consequently, finer sediments with high soil-moisture holding capacity are deposited on the downstream end of the point bar. The downstream end of the point bar can better support stabilizing vegetation given that it has lower overall energy and better soil properties than the upstream end of the point bar.

When assessments are conducted soon after a high-discharge event, it is possible for the point-bar surface to be devoid of vegetation and covered by recent deposition. Therefore, the soil specialist/geomorphologist could dig exploratory pits to determine if riparian plants exist beneath the recent point-bar deposits. Well-vegetated point bars can trap sediment, and riparian vegetation can quickly grow through the sediments if it was vigorous before burial. Point-bar deposition may indicate that the point-bar vegetation was healthy and adequate to capture sediment, filter floodwaters, and protect the banks from erosion.

Supporting Science

Because item 14 relates to whether appropriate vegetation is pioneering/colonizing and stabilizing a point bar, the same supporting science applied in items 7, 9, and 11 also applies here. The National Wetland Plant List provides wetland indicator status information that helps differentiate between riparian and upland plants (U.S. Army Corps of Engineers 2014; (Lichvar et al. 2014).

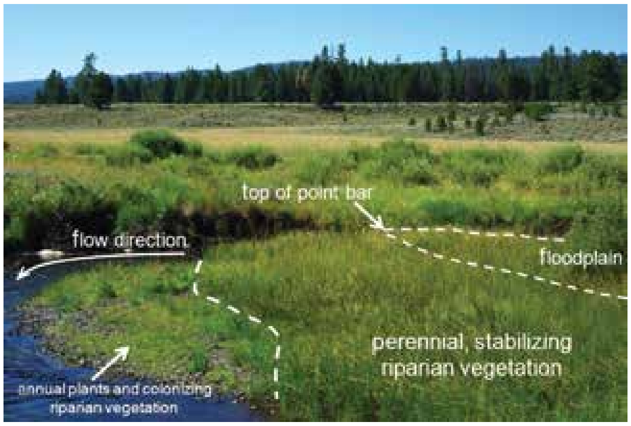


Figure 29. Stabilizing riparian vegetation will generally establish near the top of the point bar and can establish at lower parts of the point bar on the downstream end where the stream energy from high-flow events is lower.

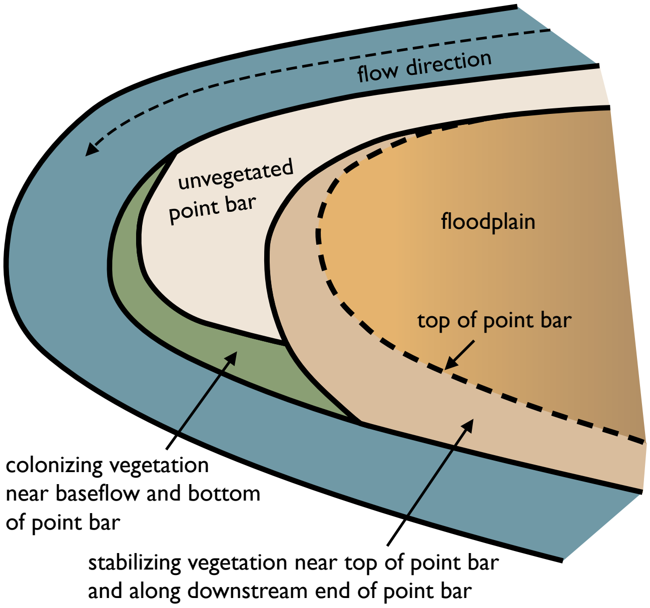


Figure 30. A schematic, planimetric view of idealized point-bar features. The top of the point bar coincides with the bankfull stage and the edge of the floodplain. Lower parts of the point bar, especially on the upstream end, are well within the active channel and may not be vegetated. The base of the point bar in contact with the base flow may contain annual plants or colonizing riparian vegetation, but such vegetation is vulnerable to scour during bankfull or flood events.

Correlation with Other Assessment Items

Item 14 is related to item 7 (recruitment of stabilizing vegetation), item 9 (stabilizing communities present), and item 11 (adequate stabilizing vegetation), focusing on the top of the point bar. Because riparian vegetation on point bars is a form of channel roughness, item 14 is also related to item 13 (floodplain and channel characteristics adequate to dissipate energy).

Item 15: Streambanks are laterally stable

Purpose

Streams located within nonconfining landforms meander back and forth across an alluvial valley bottom over time. Stream meandering is a natural process. Item 15 relates to whether the rate and type of lateral movements are within a range necessary to maintain stable channel dimensions, pattern, and profile. Bank stability serves as a proxy indicator of the amount and location of lateral movement. Item 15 draws attention to the location of bank instability and lateral stream movements. Bank erosion and deposition in a stable system occur primarily at meander bends (cutbanks and point bars, respectively; see figure 28) rather than the intervening straight segments of a stream channel.

Observational Indicators and Examples

Lateral bank instability may be an indication of poor land management activities or could result from natural environmental conditions such as high-magnitude floods. Streamgage data and historical records can be used to differentiate management-induced changes from potentially natural channel adjustments. If bank stability is adequate to maintain a stable channel or to permit recovery of an impaired channel while lateral movement of an active channel is progressing across its valley floor, the answer to item 15 would be "yes." Indicators of lateral bank stability include:

- Maintenance of a single-thread channel, provided this is the potential channel pattern.
- Formation and retention of bankfull indicators, which tend to become obscured or ill-defined in unstable conditions.
- Development of nearly continuous stabilizing vegetation along the scour line over much of the reach.
- Stable streambanks, especially on straight segments between meanders (figure 31).
- Smooth channel margins (figure 31).
- Natural rates of deposition with little to no change in bed elevation.
- Orderly progression of plant-community seral stages on the inside of a meander bend.
- Movement of the channel, primarily at meander bends, with little to no net change in dimension (channel cross-sectional area and shape; width/depth ratio), pattern (sinuosity; single vs. multithread channel), or profile (gradient), as deposition on the inside equals the erosion on the outside of a meander (figure 28). However, in a recovering system, expansion of a riparian area due to floodplain formation and a decrease in the width/depth ratio would be interpreted as a "yes" because the changes noted should be leading to a more stable and better functioning system.

In contrast, indicators of lateral bank instability, which would result in a "no" response, include:

- Evidence that the thalweg or the entire channel relocates itself with high-flow events (figure 32).
- A high degree of bank erosion along straight channel segments. Bank erosion might include slump, slough (sluff), or fracturing (figures 32 and 33).
- An overly wide channel width corresponding to a lack of bankfull indicators and to a lack of evidence of recent overbank deposition.

The field indicators of bank stability and instability must be interpreted with respect to location and stream potential. Erosion at meander cutbanks is generally natural if the rate of deposition on the point bar is roughly equal (see item 14). Bank erosion along straight channel reaches may require additional evaluation. For example, banks

Figure 31. An example of stable streambanks made of cohesive materials that are well vegetated with strongly rooted riparian plants. Stable banks exhibit smooth channel margins and should be devoid of slumps, sloughs, fractures, and slides to the degree appropriate for the channel type and bank materials.

composed of noncohesive material, such as sandy soils, might naturally have many broken segments. In comparison, cohesive materials, such as clay- and silt-rich soils, tend to have few broken banks in reaches that have reached their potential (e.g., figure 31).

Stable alluvial banks are recognized by well-developed indicators of bankfull stage, smooth and roughly parallel banks, and an erosion/deposition pattern that occurs primarily at meander bends. In contrast, unstable banks that have eroded from animal or human trampling, bank failures, or other causes develop an irregular margin, which in turn can generate highly turbulent flow and can cause accelerated bank erosion. Bank failures commonly lead to channel widening.

In figure 32, long, continuous stretches of banks (left side) have eroded along the greenline, the channel is very wide to accommodate high sediment loads, sediment has accumulated into channel bars, and the bankfull indicators are ambiguous (both banks) due to the unstable nature of the banks and rapid rates of erosion and sedimentation. Unstable banks can result from animal or human trampling, turbulence, poorly vegetated banks, and other factors that mechanically weaken the banks (bank instability is the indicator, not animal or human presence). The condition of the banks is addressed relative to the potential vegetation, stream type, and bank and bed materials. Isolated bank failures, if not excessive, may be normal and may not necessarily indicate overall instability.

Generally, when the channel experiences either lateral or vertical instability (or undergoes relatively rapid adjustments), the characteristics of the channel and banks change to reflect the instability of the system. For example, vegetation composition may shift to early-seral or more xeric communities, and erosion and sedimentation rates may increase. Also, channel morphology is poorly developed along unstable channels making it difficult to determine bankfull elevation.

In some streams, root wads, woody material, and large boulders deflect streamflow and create local scour on banks. These irregularities in the channel margin are related to natural hydraulic action and not to management activities that might have destabilized banks or induced lateral channel movement.

Figure 32. Evidence of bank erosion in an unstable channel could include slumps, sloughs, fractures, or slides. On this stream, the banks have eroded along long (several hundred meter), continuous spans. Eroded bank material is added to the channel and increases sediment load.

Figure 33. On this stream, the irregular bank margins (white dotted line on right bank) are evidence of lateral instability.

The lateral movement of some streams is constrained by existing landforms, valley topography, or bedrock (figure 34). For these streams, the appropriate answer is "NA."

Supporting Science

Lateral movement of stream channels (bank erosion) is a natural phenomenon in many riparian areas and should be considered relative to the normal adjustment processes of a stream. Lateral movement of stream channels is influenced by many factors, especially stream type, valley width, hydrologic regime, types of bank materials, and kinds and amount of stabilizing cover on the streambank. Therefore, "natural" rates of channel migration will vary by stream type and bank material (Schumm 1960, 1963) and should be determined empirically through regional studies linked to these factors or through a review of reference conditions.

Natural rates of channel adjustments should be interpreted relative to the hydroperiod, climate, and physiographic provinces of the stream reach (Wolman and Gerson 1978). For example, the stabilizing effect of riparian vegetation along perennial streams should be more extensive than the effect along an intermittent stream, where available water may be a limiting factor on plant growth. Likewise, stabilizing effects of riparian vegetation will likely be greater in humid environments than in semiarid or arid environments (Wolman and Gerson 1978). Furthermore, reaches that are limited in sediment supply may have fewer resources to rebuild fluvial landforms and to reestablish geomorphic stability than reaches with an adequate supply of sediment (Bull 1991). Finally, the ID team should distinguish between transport- and supply-limiting systems as well as climatic zones and the overall effect of the natural rates of recovery following rare, catastrophic streamflow events.

Correlation with Other Assessment Items

Because bank stability and erosion can alter channel dimension (channel shape and size), item 15 is strongly related to item 3 (sinuosity, gradient, and width/depth ratio in


Figure 34. Landform-controlled streams have little opportunity to move laterally.

balance). Lateral stream movement usually occurs through bank erosion; thus, item 15 is also strongly correlated to item 11 (adequate stabilizing riparian vegetation).

Item 16: Stream system is vertically stable (not incising)

Purpose

Item 16 pertains to whether the elevation of the channel bed is stable or lowering due to channel incision. Incision could be the result of natural processes, such as loss of vegetation related to climatic fluctuations, wildfire, extreme hydrologic events, or intrinsic geomorphic thresholds (Schumm 1973, 1979), or a consequence of certain land uses or human activities, such as urbanization, logging, road construction, and grazing. Channel incision might reflect systemwide adjustment related to changes in the base level of a downstream lake or reservoir or to incision of tributaries in response to incision of main-stem channels. Channel incision adversely affects the ability of streams to dissipate energy by reducing hydrologic access to floodplains, store water by reducing recharge of alluvial aquifers, and maintain a diverse and robust riparian plant community due to a drop in the water table.

Item 16 is specific to short cycles of sediment storage and removal, where episodes of channel incision are rapid (occurring over a few years to a few decades) and result in noticeable bed lowering. The timeframe of years to decades fits within the realm of a management time scale. Item 16 does not speak to the gradual lowering of landscapes that result over geologic time scales of thousands to millions of years. Also, item 16 does not consider localized channel scour, which can produce irregularities in the elevation of the channel bed but does not indicate systemic channel incision.

This item addresses vertical adjustments occurring today, not those that have occurred in the past. This item deals only with the *lowering* of a streambed and not aggradation, which is addressed in item 17.

Observational Indicators and Examples

If a riparian area has no evidence of vertical incision (e.g., headcuts), the answer to item 16 is "yes."

Field indicators of vertical incision that result in a "no" response might include:

- Presence of one or more **knickpoints**, which are abrupt, vertical or nearly vertical changes in bed elevation along the longitudinal profile, or **knickzones**, which are more gradual changes in elevation, occurring in an oversteepened part of the longitudinal profile (figure 35).
- Greater height from channel bed to the floodplain downstream of a knickpoint or knickzone than upstream of the knickpoint or knickzone (figure 35).
- A channel that has lost hydrologic connection to a floodplain (though this may also be an inherited condition from a past period of incision) (figure 36).

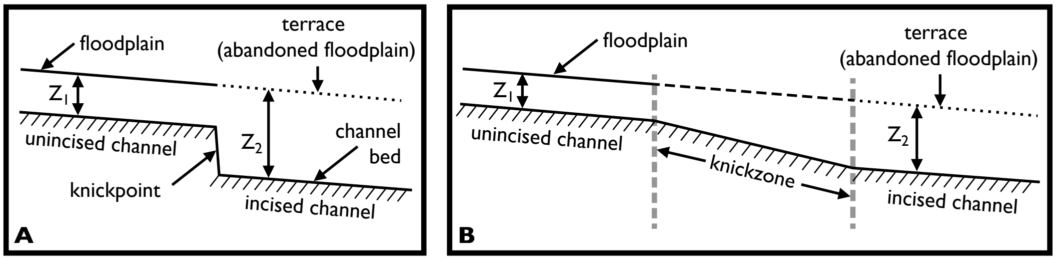


Figure 35. Longitudinal gradient of a stream across a knickpoint (A) and across a knickzone (B). A visual test to determine whether a knickpoint is an active headcut is to measure the height from channel bed to bankfull or floodplain elevation upstream and downstream from the knickpoint. If the height between these is greater downstream (Z_2) than upstream (Z_1) of the knickpoint, then the knickpoint is likely an active headcut. In contrast, when the channel drops across a step in a step-pool sequence (or across a riffle in a riffle-pool sequence), the floodplain surface drops too, so the heights, Z_1 and Z_2, remain equal.

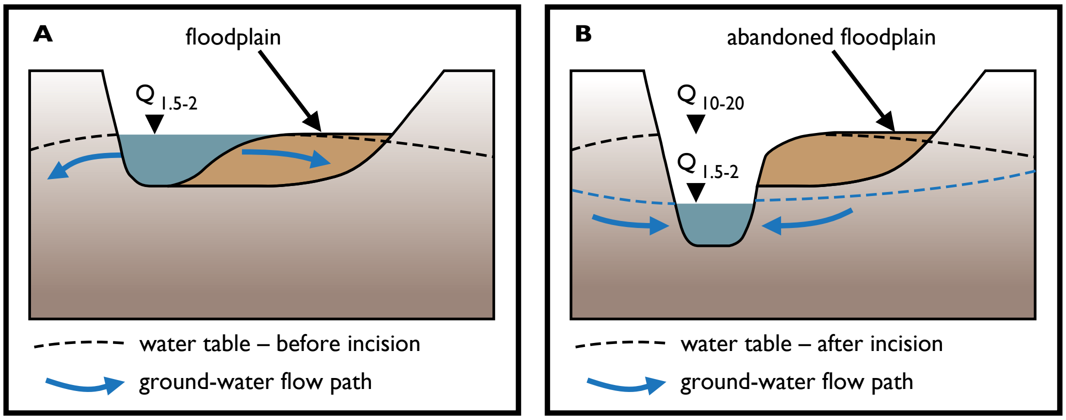


Figure 36. Schematic diagrams illustrating the relationship between channel cross-sectional area and discharges of different recurrence intervals ($Q_{1.5-2}$ represents the bankfull discharge with a recurrence interval of 1.5 to 2 years and Q_{10-20} represents the discharge with a recurrence interval of 10-20 years). Diagram (A) represents an unincised channel where the bankfull discharge completely fills the channel and is able to spill onto the floodplain with any increase in discharge. Diagram (B) illustrates an incised channel with a cross-sectional area that can convey a discharge that is considerably larger than the 1.5- to 2-year event and that will inundate the adjacent (abandoned) floodplain infrequently.

- A lack of bankfull indicators and an enlarged cross-sectional area that is much larger than the cross-sectional area needed to convey the mean-annual flood (figure 36).
- Gullylike or arroyolike channel morphology with vertical or nearly vertical walls and little or no sediment at the toe slope.
- A channel scoured to a resistant layer or bedrock with little or no sediment within the channel bed; i.e., recovery is not imminent.
- A dewatering alluvial aquifer as indicated by seepage on banks or suggested by reduced vigor of riparian vegetation when the water table declines.
- Upland vegetation encroaching onto an abandoned floodplain or high streambanks or other riparian locations due to a drop in the water table (figure 36).

If a stream channel has incised but shows development of a new, inset floodplain, the answer to item 16 would be "yes." The formation of an inset floodplain implies channel incision has halted, and the channel has regained vertical stability.

For a reach that has an active headcut resulting in channel incision, the answer to item 16 would be "no." Also, if an active headcut is downstream of the assessed reach and there is no grade control or impediment to prevent migration of the headcut into the assessed reach, then the answer to item 16 would be "no."

The headcut could either be distinct, like a knickpoint, or more subtle, like a knickzone (figure 35). Visual clues to a knickzone might include changes in the cross-sectional area of the channel above, through, and below the knickzone; an increase in height between the channel bed and floodplain surface downstream of the knick; or coarser substrate on the channel bed reflecting greater scouring power of the stream through the steeper knickzone.

Another result of a downstream headcut is dewatering of the alluvial aquifer and a corresponding drop in the water table (addressed under items 4 and 8).

Some stream types, such as step-pool or cascading streams, have numerous vertical scarps or short sections with a steep gradient. These steps might have the form and appearance of a headcut, but they typically are stable; armored by coarse, anchored boulders or wood; and not associated with channel incision. If a stream type naturally contains step pools or cascades, then the answer to item 16 would be "yes" provided the steps are indeed stable. Likewise, vertical scarps across resistant rock layers are not susceptible to land management activities and do not constitute headcuts; therefore, the channel is likely not incising.

If a channel's stability at potential is controlled by bedrock, item 16 would be answered "yes." If the channel is actively incising through alluvium to expose bedrock, item 16 would be answered "no."

If item 16 is answered "no" because of a headcut moving upstream, then the reach above the headcut to a point where there is some geologic or structural grade control is FAR or NF regardless of other factors.

Supporting Science

Vertical instability results in channel incision and loss of connection to a floodplain and the associated riparian area. If vertical instability of the stream is suspected, determining whether adjustments in bed elevation are the result of local conditions or systemwide instability may be useful. Adjustment processes that affect entire fluvial systems often include upstream-progressing incision, downstream aggradation, channel widening or narrowing, and changes in the amount and size of sediment. These processes differ from localized processes, such as scour and fill, which can be limited in magnitude and extent. Scour and fill occur over periods of hours to days and affect local areas in response to high-flow events. In contrast, processes of incision and aggradation usually affect all or much of a stream reach or an entire drainage basin and may be most noticeable over a period of several years to several decades. Channel adjustment processes such as incision and aggradation can exacerbate local scour problems; bed-level adjustments may result in bank instability, channel incision, or changes in channel pattern. The consequences of local scour are typically undetectable within a short distance (e.g., a length equal to a few channel widths) of the scour.

Changes to the hydrologic function or sediment production in uplands will commonly trigger adjustments to channel position or channel pattern. Hydrologic changes might include a shorter response time (flashy events) and greater volume of overland runoff. Sediment load could change as a consequence of upland activities such as logging, wildfire, chronic overgrazing, or other natural or management actions that decrease protective vegetation cover, decrease interception of precipitation, or decrease storage of precipitation.

Other anthropogenic activities that can be related to rapid channel adjustments include urbanization (Wolman 1967; Dunne and Leopold 1978); road construction, which can alter natural hydrologic processes by concentrating and diverting water into road ditches and culverts; dam construction, which can alter volume, time (seasonality), frequency, and duration of stream discharge and sediment (e.g., Williams and Wolman 1984; Friedman et al. 1998; Magilligan et al. 2003); and interbasin water transfers, which can alter the volume of streamflow. This is not an exhaustive list of human impacts to streams, but rather a list of some common practices that have well-documented instances of causing stream incision.

In contrast to systemic aggradation and incision, with predictable changes in channel evolution upstream or downstream of a knickpoint, instability problems related to local conditions can often be attributed to redirection of flow caused by debris or structures (e.g., beaver dams). During moderate and high flows, obstructions often result in vortices and eddies that produce local scour, erosion of bank toes, and ultimately, bank failures. Constrictions in the channel from debris accumulations or structures can also cause a backwater condition upstream, with acceleration of flow and scour through the constriction. Local scour should not be interpreted as channel incision.

Channel incision of a magnitude and rate sufficient to be easily observed and measured is indicative of systemic instability. However, caution is needed when interpreting changes in bed elevations along sand-bed channels. Scour and fill in some sand channels may approach 10 feet or more during the passage of a single flood event with virtually no long-term change in streambed elevation (i.e., no incision). Although such channels may be considered vertically stable with respect to bed elevations, they may or may not be functioning properly for their landscape setting.

Correlation with Other Assessment Items

Item 16 addresses vertical adjustments related to channel incision. Item 17 (stream in balance with water and sediment supplied) is broader in scope than item 16 and addresses vertical adjustments related to either channel incision or channel aggradation. Also, item 17 considers changes in channel size and shape with no net change in channel elevation.

Item 16 is also related to items 1 (floodplain frequently inundated), 3 (sinuosity, gradient, and width/depth ratio in balance), 4 (riparian area expanding), and 8 (maintenance of soil moisture). When a channel incises, it becomes less likely that large flow events will overtop the banks and access the floodplain (item 1). Commonly, channel incision coincides with channel straightening and increased channel gradient (item 3), all factors which reflect increased and concentrated energy in the channel. When channels incise, the alluvial aquifer drains into the lowered channel and the water table declines. If the decline is greater than the effective rooting depth of the riparian plants, the plant community will also reflect drier conditions, which may be reflected in the answers to items 4 and 8.

Item 17: Stream is in balance with the water and sediment that is being supplied by the drainage basin (i.e., no excessive erosion or deposition)

Purpose

Streams transport water and sediment. To answer item 17, the ID team will need to look for any evidence that the sediment supply and transport capacity are out of balance, thus causing channel incision or excessive aggradation.

Observational Indicators and Examples

Item 17 is answered “no” whenever there is an observable imbalance between sediment supply and transport capacity. Field indicators of systems where sediment supply exceeds transport capacity might include:

- Formation of mid-channel bars or development of a braided channel bed in a stream that has the potential for a single-thread channel.
- Rapid floodplain aggradation with burial of riparian vegetation and floodplain soils.
- Burial of fence posts or other modern cultural artifacts.
- A rise in channel-bed elevation related to an overaccumulation of sediment in the channel.
- Incongruities in the particle-size relations of bedload, streambed surface textures, and subsurface textures.

Field indicators of systems where driving forces exceed resisting forces include many of those features described under item 15 (lateral bank stability) and item 16 (vertical incision), particularly:

- Erosion (slump, sloughing, fracturing, slides) of unstable streambanks (figures 32 and 33).
- Development of knickpoints or knickzones with active upstream migration of headcuts.
- Greater height from channel bed to the floodplain downstream of a knickpoint or knickzone than upstream of the knickpoint or knickzone (figure 35).

- A channel that has lost hydrologic connection to a floodplain (though this may be an inherited condition from a past period of incision) (figure 36).
- Channel cross-sectional areas that are enlarged (width and/or depth has increased beyond what is expected) and can convey discharges that are much greater than the mean-annual flood (figure 36).

Different channel adjustments tend to occur in a given order, reflecting the magnitude of the imbalance and the time required for various adjustments to appear. For example, when sediment supply and transport capacity are imbalanced, a first response may be in the grain size of the streambed. A subsequent response may be formation or removal of in-channel bars, progressing next to channel incision or bed aggradation, then bank erosion, and ultimately to an adjustment in channel slope (Wilcock et al. 2009).

Natural channels can be classified as either single-thread or multiple-thread (braided or anastomosing) channels. Factors that determine channel pattern include sediment supply, sediment size (i.e., suspended versus bedload) and particle cohesion, stream discharge, and stream slope. A glacial outwash stream is an example of a system with a naturally braided channel pattern. Braided streams are characterized by highly variable discharge, high bank erosion, high sediment loads, deposition occurring as both longitudinal and transverse bars, and annual shifts of the bed location. Similar systems can be found where sand is the dominant bed material. Remember that each riparian area is assessed according to its potential.

If a stream has a single-thread channel, shows no evidence of mid-channel bars, and is not aggrading as a result of excess sediment from the watershed, the answer to item 17 would be "yes." If the flow in a stream is increased from an interbasin transfer or diversion, and excessive erosion or deposition is taking place as a result of this increased flow, the answer to item 17 would be "no."

If a channel is braided and has high streambank erosion, and these conditions are consistent with the landscape setting (i.e., natural sediment load, gradient, and discharge), the answer to item 17 would be "yes." If braiding or bank erosion are the result of poor land management, such as clearcut logging or road construction (Swanson and Dyrness 1975; Beschta 1978), hydraulic mining of placer deposits (James 1991, 1999), excessive erosion from agricultural practices (Knox 1977; Trimble 1983, 1985), other anthropogenic actions, such as the operation of a dam (Williams and Wolman 1984), or water withdrawals, the answer to item 17 would be "no."

Particularly in gravel-bed streams, the presence of excess sediment might be detected by a comparison of the bedload with both the streambed's surface texture and the subsurface texture. When the modern bedload is similar to the substrate, there is reason to believe the sediment supply and transport capacity are relatively well balanced. When the two differ substantially, sediment supply and transport capacity may be out of balance.

Item 17 should never be answered "NA"; it will always have a "yes" or "no" answer.

Supporting Science

Stream channels are constantly adjusting to the volume, seasonality, duration of streamflow, and amount and caliber of sediment (Lane 1955; Leopold and Maddock 1953). Lane (1955) described the types of channel adjustments (aggradation or incision) that can occur in response to changes in sediment supply and transport capacity. Additional stream responses to disequilibrium can include a change in channel gradient, stream sinuosity, channel size and shape, and changes in sediment caliber. Interpretation of channel adjustments requires an understanding of changes in streamflow and sediment production throughout the drainage.

The processes of channel adjustment should be evaluated with respect to both temporal and spatial considerations. For example, channel adjustments related to rare, high-magnitude streamflow events (e.g., a 50- or 100-year flood) can change channel and valley bottom conditions immediately after such events, but they may not reflect any problems related to poor stream function. Likewise, headwater streams that produce large quantities of sediment need to be evaluated separately from reaches that transport and store sediment. The relationship between sediment load and transport capacity, especially for gravel-bed streams, is discussed by Parker (1990), Bunte and Abt (2001), Pitlick et al. (2009), and Wilcock et al. (2009), among many others.

Correlation with Other Assessment Items

This item is related to items 3 (sinuosity, gradient, and width/depth ratio in balance), 5 (riparian impairment from watershed is absent), 13 (floodplain and channel characteristics adequate to dissipate energy), 15 (lateral stability), and 16 (stream system vertically stable). Changes in sediment load or transport capacity have the effect of altering stream power, which in turn can produce changes in channel gradient, shape, and sinuosity (item 3). Item 17 and item 5 are both dependent on the amount of water and sediment supplied by the drainage basin. However, the intent of item 5 is to determine where the cause of any riparian deterioration is occurring; i.e., if the cause is activities occurring within the immediate riparian area, item 5 would be answered "yes," and if the cause is activities in the uplands or in riparian reaches that are upstream of the assessed reach, item 5 would be answered "no."

Evidence of rapid aggradation from excess sediment is not only observed as in-channel deposits, but it also is commonly found on the floodplain and in overflow channels. Therefore, items 13 and 17 can be related. If a stream is out of balance in terms of lateral movement in item 15, item 17 would also reflect that imbalance. Whereas item 16 is exclusively about channel incision and active headcut migration, item 17 is broader in scope and includes processes of both channel erosion from downcutting, channel erosion from lateral enlargement, and stream aggradation of the channel or floodplain.

8. Finalizing the PFC Assessment

Determine the Functional Rating

After documenting their observations on the assessment form, the ID team collectively determines a functional rating based on review and discussion of their "yes" and "no" responses and their documented comments for each item on the form. The ID team assigns the rating that most appropriately corresponds to how the assessment items were addressed: proper functioning condition, functional–at risk, or nonfunctional.

A lotic riparian area is considered to be in **PFC** when adequate vegetation, landform, or woody material is present to:

- Dissipate stream energy associated with high waterflow, thereby reducing erosion and improving water quality.
- Capture sediment and aid floodplain development.
- Improve floodwater retention and ground-water recharge.
- Develop root masses that stabilize streambanks against erosion.
- Maintain channel characteristics.
- Provide values associated with riparian areas.

The components of this definition are in order relative to how processes work on the ground.

If a riparian area is rated as **FAR**, it is in limited functional condition; however, an existing landform, water, or vegetation attribute makes it susceptible to impairment.

If a riparian area is rated as **NF**, it is clearly not providing adequate vegetation, landform, or woody material to dissipate stream energy associated with moderately high flows and thus is not reducing erosion, improving water quality, etc.

The PFC assessment is designed to assess whether the physical elements (abiotic and biotic) are in working order relative to potential. When these physical elements are in working order, channel characteristics develop that can provide habitat for wildlife and other uses. Functionality comes first, and then functionality may lead to the achievement of desired conditions.

Because of the variability in types of lotic riparian areas (based on differences in climatic setting, geology, landform, hydrology, and substrate) and variability in the severity of individual factors relative to an area's ability to withstand relatively high-flow events, there is no set number of "no" responses required to determine whether an area is rated as FAR or NF. If a riparian area has the necessary elements, then it has a *high probability to withstand relatively high-flow events.* If all the responses on the assessment form are "yes," the reach is undoubtedly meeting these criteria and would be rated as PFC. If some responses are "no," the reach may still meet the definition of PFC, depending on the

nature and severity of the "no" responses. ID team discussion is critical to making these determinations.

The definition of PFC includes "adequate vegetation, landform, **or** woody material" because not all streams and riparian areas process the energies of flowing water in the same way or have the same potential plant community. For example, many areas in the Great Basin have a mixed willow and sedge/rush vegetation potential. High-energy stream reaches require some combination of both stabilizing woody and herbaceous vegetation (and sometimes rock and woody material) to dissipate energy, whereas lower energy or low-gradient reaches are often able to dissipate energy with only the herbaceous components.

One example of where landform drives stream energy dissipation is the Yellowstone River below the Lower Falls in Yellowstone National Park. The canyon's geology and bedrock channel are such that they dissipate stream energy associated with high waterflows. This reach of the Yellowstone River has no potential to produce vegetation, does not need vegetation to dissipate energy, and is functioning properly.

High-flow events for assessing PFC are 5-, 10-, and 25-year events. To sustain a given riparian area over time, the energies associated with high-flow events have to be accommodated. Experience has shown that riparian areas rated as PFC generally withstand these events. Extreme events such as the 50- to 100-year or larger events occur infrequently and have such power that riparian areas in PFC may unravel, at least in places. Reaches that are in PFC prior to these extreme events can generally recover at a faster rate than reaches rated as FAR or NF.

A **FAR** riparian area may possess some or even most of the elements in the PFC definition, but at least one of its attributes/processes gives it a *high probability for **impairment** during a relatively high-flow event(s).* Most of the time, several "no" responses will be evident because of the correlation among items on the assessment form. If these "no" responses, in the ID team's opinion, collectively provide a high probability for impairment in relatively high-flow events, then the area is rated as FAR. Figure 37 provides an example of a situation where only one "no" response can put a riparian area at risk. *If a stream reach has a headcut moving upstream (item 16), then the reach above the headcut to a point where there is some geologic or structural grade control is rated as FAR or NF regardless of other factors.*

Figure 37. A headcut is moving upstream through a meadow, making the riparian area upstream of the headcut functional–at risk.

Trend toward or away from PFC must be described when a rating of FAR is given. Trend is the direction of change in an attribute(s) over time and can be addressed two ways. If trend is determined using photos, monitoring data, detailed inventories, and any other measurement or documentation to compare past conditions to present conditions, it is defined as "monitored trend." Monitored trend is described as upward, downward, or static. If this information is not available, indicators of "apparent trend" may be used to estimate trend during the assessment process. Apparent trend is defined as "an interpretation of trend based on observation and professional judgment at a single point in time" (Society for Range Management 1998) and is described as upward, downward, or not apparent.

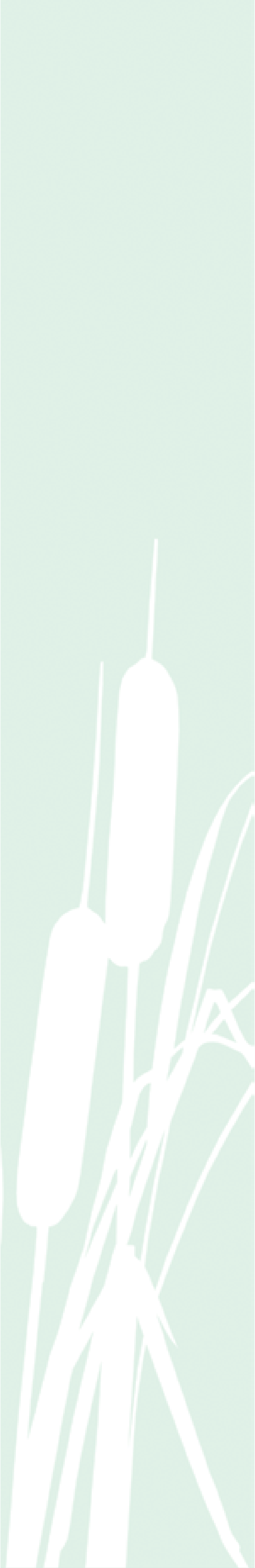
ID teams need to indicate which trend method was used and provide their rationale for the selected trend determination on the assessment form.

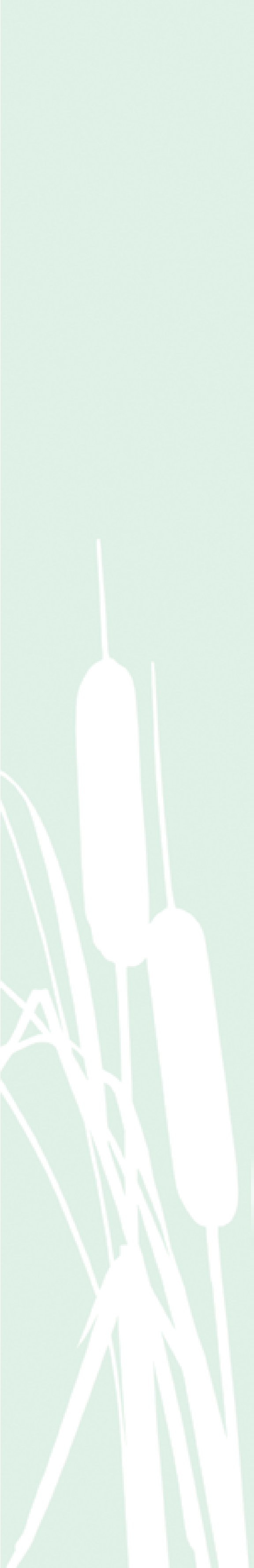
Riparian areas rated as **NF** *clearly lack the elements* listed in the PFC definition. Usually NF ratings translate to a preponderance of "no" responses on the assessment, but not necessarily all "no" responses. A laterally unstable stream may still retain a floodplain, the upland watershed conditions may be acceptable, and the stream may be vertically stable, but still clearly nonfunctional.

Although it may appear that the selection of a final rating category is the primary objective of the PFC assessment, the observations and comments for each item provide specific, critical information that is useful for subsequent management, restoration, and monitoring efforts and for estimating the recovery trajectory and rate. This information may reveal important opportunities and is a key benefit of the PFC assessment.

Riparian areas can function properly before they achieve their potential. The PFC definition does not mean that potential or optimal conditions for a particular species have to be achieved for an area to be considered functioning properly. Figure 38 provides a simplified example of the relationship between PFC and channel/vegetation succession for one kind of stream reach; *the relationship may be different for other areas because of differences in potential and the way specific systems progress/regress.*

In the hypothetical example shown in figure 38, assuming riparian recovery continues uninterrupted, the riparian area will evolve from bare ground to its potential. The riparian area, including its channel and streambank vegetation, will progress through phases of NF, FAR, and PFC. *In this example, PFC occurs at the mid-seral state, though this is not always the case.* PFC does not occur at a single point in time; depending on which attributes and processes are required for function, it may occur from early-seral to late-seral states (although PFC occurs less commonly in streams at an early-seral state than those that are in a more advanced state).





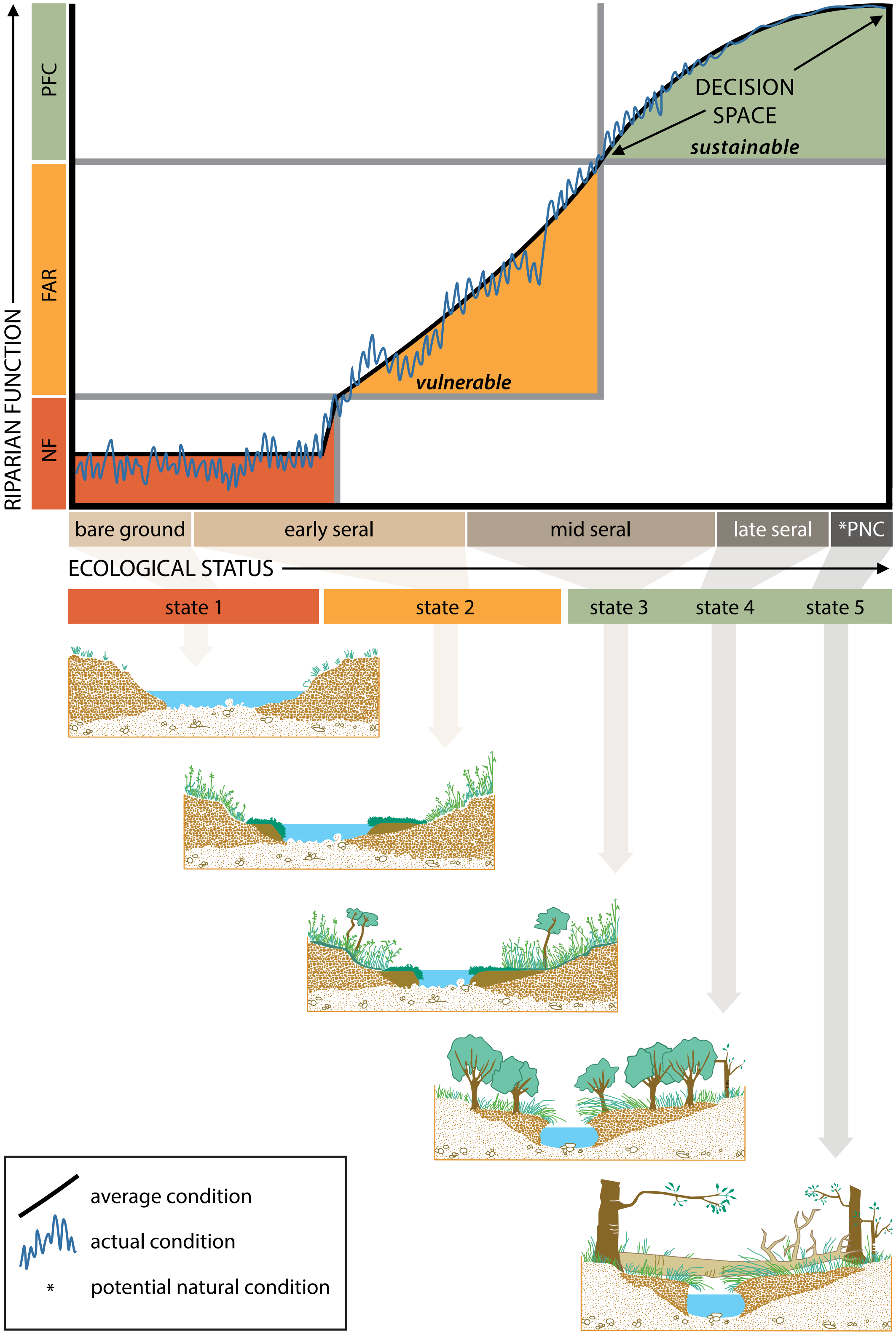


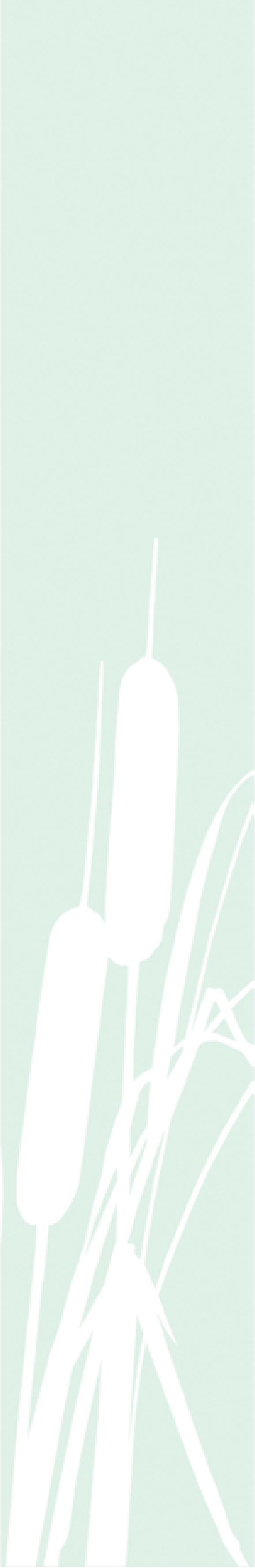
Figure 38. An example of succession as it relates to riparian recovery and physical function. Streams rated functional–at risk are vulnerable to impairment from moderate- to high-flow events. Streams in PFC are better able to withstand impairment from these events and thereby can sustainably produce certain values. Not all streams will follow this successional progression.

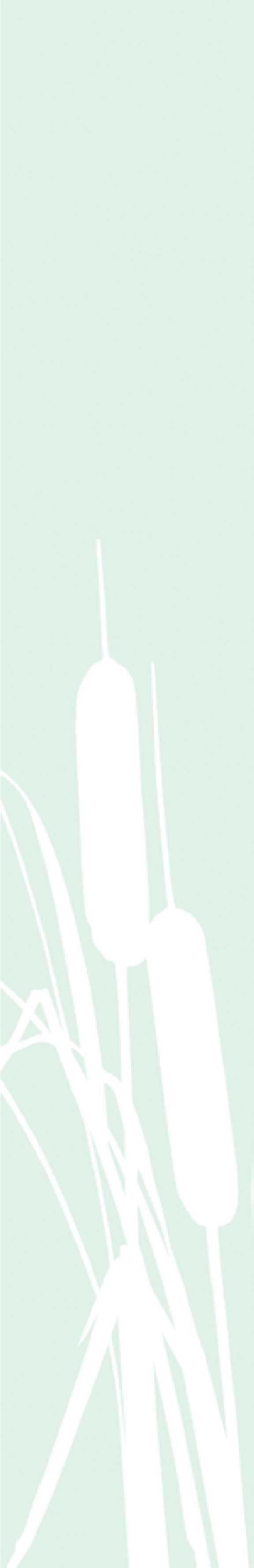
“States” represent distinct conditions at a defined point in time. A stream reach may remain at one state or condition for an undetermined length of time because of coinciding circumstances of management and climate. Progress toward a higher state or condition may at times be impeded by greater natural stresses associated with high flows. Regression toward a lower condition may be dependent on exceeding a threshold of stability, progressing slowly at first, and then rapidly declining as the threshold is crossed. In reality, during recovery, the progress will appear like a stock market graph with a series of peaks and valleys and with the average over time representing progress toward a higher condition. In any condition, from FAR to desired condition, an event, either human-induced or natural (fire, volcanic eruption, floods, dewatering, etc.), can cause the area to regress to a lower condition. A much greater disturbance event is necessary to cause the condition to regress in areas that are in PFC than in areas that are FAR. Not all streams will follow this same progression (Gebhardt et al. 1990; McBain and Trush 1997). Impairment can occur quickly and recovery can often be slow, depending on reach-specific attributes and processes. In general, this is why it is desirable to maintain streams in PFC.

As a system progresses towards potential natural condition, a number of physical changes begin to occur. These include reduced erosion, sediment capturing, and improved floodwater retention (when adequate vegetation, landform, or woody material are present to dissipate energy associated with moderately high flows). As the physical aspects of a system begin to function, the process of developing pools and other channel characteristics that provide habitat for fish, waterfowl, and other uses is initiated. The physical aspects have to be in working order to sustain the channel characteristics that provide habitat and other resource values (Fischenich 2006; Somerville 2010).

At various states within this successional process, the stream can provide resource values for different uses. For the example in figure 38, optimal conditions for grazing occur when forage is abundant and the area is stable and sustainable (mid-seral state). Wildlife goals depend upon the species for which the area is being managed. If the riparian area in figure 38 is to provide habitat for shrub-nesting birds, the optimum conditions would occur from the mid-seral to late-seral states. Trout habitat conditions also would be optimum from the mid-seral to late-seral states. Desired plant communities would be determined based on management objectives through an interdisciplinary approach. The threshold for any goal is at least PFC because riparian areas with any rating below PFC are not sustainable. Until PFC is attained, the “decision space”—the parameters within which management decisions can be made—that is available to managers to emphasize one resource value over another is limited.

As streams recover and attain PFC, they will generally continue to progress towards some advanced condition unless management actions are implemented to modify the process. The decision space in figure 38 does not imply that management has unlimited control over every riparian attribute or process nor does it imply that it is always easy to manipulate riparian attributes to feature one value over another (McBain and Trush 1997).





Complete Reach Information and PFC Assessment Forms

For a PFC assessment to be finalized, the ID team completes the following *for each reach:*

- Reach information form (including map).
- PFC assessment form.
- Riparian plant list form or similar list (strongly recommended)
- Photographs supporting the PFC assessment (with documentation).
- Assessment results entered into the appropriate agency database (as needed).

The forms, as well as detailed instructions for completing them, are included in appendix A.

In addition, if multiple reaches are completed, the ID team can summarize their findings in a comprehensive report. A report provides helpful information for future projects and analyses. A suggested outline for the report is shown below:

I. Introduction
II. PFC Assessment Results
  A. Description of assessment area
  B. Reach delineation/stratification
  C. Description of potential(s)
  D. Reach narratives (summary of PFC assessment results in narrative form)
  E. Observations/findings
  F. Issue identification and management recommendations
III. References (soils surveys, stream classification, etc.)
IV. Appendices
  Appendix 1: Reach information, plant list, and PFC assessment forms
  Appendix 2: Photos and captions
  Appendix 3: Maps with reach breaks and photo waypoints
  Appendix 4: Waypoint/photopoint log

Depending on complexity, a table of contents, executive summary, methods summary, and details of stream classification may also be included.

Appendix A—Instructions and Forms

The Reach Information Form and PFC Assessment Form must be filled out for each assessment reach. Completion of the Riparian Plant List Form is also strongly recommended to facilitate recordkeeping and documentation; this form may be altered based on local needs. Photographs should be cataloged to ensure that important information about them, such as location, is retained over time.

Reach Information Form (Lotic) – Instructions

Background Information

- Provide pertinent background information.
- List all members of the core ID team by name and discipline. Include others not on the core ID team and identify their role as extended team members.
- Indicate the nature of the assessment method (i.e., complete field reconnaissance, inspection of selected representative areas, or a combination using remote imagery and selective field inspections).
- Attach an aerial image, USGS 7.5-minute topographic map, or GIS map showing the location of the reach with reach breaks indicated.

Reach Break Location

- Record the upper and lower reach breaks in one or more geographic systems (latitude and longitude in degrees, minutes, and seconds or in decimal degrees, or Universal Transverse Mercator (UTM) coordinate system). Provide the datum (e.g., North American Datum 1927 (NAD27), North American Datum 1983 (NAD83), or World Geodetic System 1984 (WGS84)). Omission of the datum can result in aberrations whenever the geographic data are projected in a different coordinate system than the one used to fix the location originally. If UTM coordinates are used, also indicate the UTM zone.
- Provide the rationale used for determining the reach breaks. For example, "Reach begins at transition from confined bedrock reach to unconfined alluvial reach," or "Reach ends at fence line along private land."

Description of Potential and Rationale

- Describe the potential natural condition (or altered potential) for the assessed reach and account for the hydrologic regime, the plant communities, and the channel and floodplain characteristics that should exist at potential. Give the rationale used for determining potential.

Other Assessment or Monitoring Data

- Indicate if the reach has been assessed previously. If it has been assessed, include the date(s), previous functional rating(s), and any trend information.
- Indicate if a DMA has been established within the reach and when the DMA was monitored.
- Include copies of existing data to inform the current assessment effort.

Reach Information Form (Lotic)

I. Background information: Date: ____________

Riparian area/stream name: ______________________ Reach ID: ____________

Management unit (allotment/pasture, other): ______________________

Administrative unit/state: ______________________

ID team members: ______________________

____

Assessment method: Reach length (miles/km): ____________

☐ Complete reconnaissance

☐ Selective inspection of representative areas

☐ Remote imagery with selective ground inspection

Location: Attach aerial image, USGS 7.5-minute topographic map, or GIS map with reach breaks indicated.

II. Reach break location:

Reach starting point (upstream)	**Reach ending point (downstream)**
________ N. Lat. UTM E ________ m	________ N. Lat. UTM E ________ m
or	or
________ W. Long. N ________ m	________ W. Long. N ________ m

Positions by GPS? ☐ Yes ☐ No Photos taken? ☐ Yes ☐ No UTM Zone: ____________

Datum: ☐ NAD27 ☐ NAD83 ☐ WGS84 ☐ Other (specify): ____________

Rationale for reach breaks: ______________________

____

____

III. Description of potential and rationale (should include description of hydrologic regime, stream type(s), and riparian plant communities at potential; may include additional information such as valley type, gradient, entrenchment ratio, sinuosity, width/depth ratio, and bed and bank materials):

____

____

____

____

____

IV. Other assessment or monitoring data or information about the reach:

PFC Assessment Form (Lotic) – Instructions

1. Prior to completing the form, examine the entire reach using the selected approach (complete reconnaissance or selective inspections). Take notes and photographs and discuss key attributes observed along the reach.
2. Complete the form after the reach has been examined. Examining multiple reaches and then completing several forms at once is not advised. The end of an assessment reach (reach break) where the team completes the form often coincides with an ecotone. Ecotones are generally not representative of average reach conditions, and teams should not use observations from the ecotone to represent reach conditions.
3. Mark the “yes,” “no,” or “NA” box for each item on the list unless the ID team concludes that there is strong evidence that neither a conclusive “yes” nor “no” is appropriate or that both apply; if this is the case, mark both the “yes” and “no” boxes for that item. This approach should be used sparingly, and the team should work to make a conclusive determination of a “yes” or “no” for each item. The “NA” box is provided for reaches that do not have the potential for that item.
4. Document the response to each item with a short narrative describing the ID team’s rationale. Because PFC is a qualitative assessment, providing the rationale for each item is important. As the assessment form is being completed, refer to chapters 5-7 for the purpose of each item and useful observational indicators.
5. Following the completion of all 17 items, read the definitions of the three functional categories, discuss how the assessment items were rated, and determine the functional rating category of the reach. Provide a short narrative describing the rationale used for the selected rating. See chapter 8 for a detailed discussion.
6. Address trend for FAR reaches. Trend can be addressed by using “monitored trend” (using supplemental information) or “apparent trend” (based on a one-time observation of indicators). Provide a short narrative describing the rationale used for ascertaining trend. See chapter 8 for a detailed discussion.
7. Based on the condition of the reach, estimate the status of the reach within the PFC and FAR categories on the thermometer scale to the nearest third of the category.

   For the PFC range, the upper third is for those reaches where the vegetation community is approaching PNC and the channel dimensions, pattern, and profile exhibit high stability. In contrast, the lower third of the PFC range represents reaches where the vegetation communities and the channel’s dimensions, pattern, and profile are adequate for dissipating energy and maintaining stability, but there are appreciable opportunities for increased channel stabilization and maturation of riparian plant communities.

   For the FAR range, the upper third of the FAR range represents reaches that are a small step away from PFC. In contrast, the lower third is just a step above the NF range.

   NF is nonfunctional! There is no need to subdivide this category. NF reaches are severely degraded and incapable of functioning properly under the current conditions.

The purpose of using this scale on the thermometer is to provide additional information for decisionmaking. For example, FAR reaches at the bottom of the scale may be managed differently than those almost at PFC.

8. If the reach is rated FAR or NF, determine if there are factors contributing to those conditions that are outside the control of the manager. If the reach is rated PFC, document any factors that may affect the achievement of desired condition for other values. Indicate “yes” or “no” and the factors that are contributing, and describe them in the remarks section.

9. Complete summary remarks and use additional space if needed. Written observations provide solid documentation of items that drive the functional rating. A photo log can provide visual rationale.

PFC Assessment Form (Lotic)

Riparian area/stream name: ______________________ Reach ID: __________ Date: ______

Yes	No	NA	HYDROLOGY
			1) Floodplain is inundated in "relatively frequent" events.
Rationale:			
			2) Beaver dams are stable.
Rationale:			
		▨	3) Sinuosity, gradient, and width/depth ratio are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region).
Rationale:			
			4) Riparian area is expanding or has achieved potential extent.
Rationale:			
		▨	5) Riparian impairment from the upstream or upland watershed is absent.
Rationale:			

Yes	No	NA	VEGETATION
			6) There is adequate diversity of stabilizing riparian vegetation for recovery/maintenance.
Rationale:			
			7) There are adequate age classes of stabilizing riparian vegetation for recovery/maintenance.
Rationale:			
			8) Species present indicate maintenance of riparian soil-moisture characteristics.
Rationale:			
			9) Stabilizing plant communities capable of withstanding moderately high streamflow events are present along the streambank.
Rationale:			
			10) Riparian plants exhibit high vigor.
Rationale:			
			11) An adequate amount of stabilizing riparian vegetation is present to protect banks and dissipate energy during moderately high flows.
Rationale:			

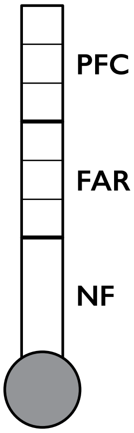
			12) Plant communities are an adequate source of woody material for maintenance/recovery.
Rationale:			

Yes	No	NA	GEOMORPHOLOGY
		▨	13) Floodplain and channel characteristics (i.e., rocks, woody material, vegetation, floodplain size, overflow channels) are adequate to dissipate energy.
Rationale:			
			14) Point bars are revegetating with stabilizing riparian plants.
Rationale:			
			15) Streambanks are laterally stable.
Rationale:			
		▨	16) Stream system is vertically stable (not incising).
Rationale:			
		▨	17) Stream is in balance with the water and sediment that is being supplied by the drainage basin (i.e., no excessive erosion or deposition).
Rationale:			

Summary Determination

Functional rating (check one)

☐ Proper functioning condition
☐ Functional–at risk
☐ Nonfunctional



Trend (check one)

Monitored trend

☐ Upward
☐ Downward
☐ Static

Apparent trend

☐ Upward
☐ Downward
☐ Not apparent

Rationale for rating:

Rationale for trend:

Are there factors present preventing the achievement of PFC or affecting progress towards desired condition that are outside the control of the manager?

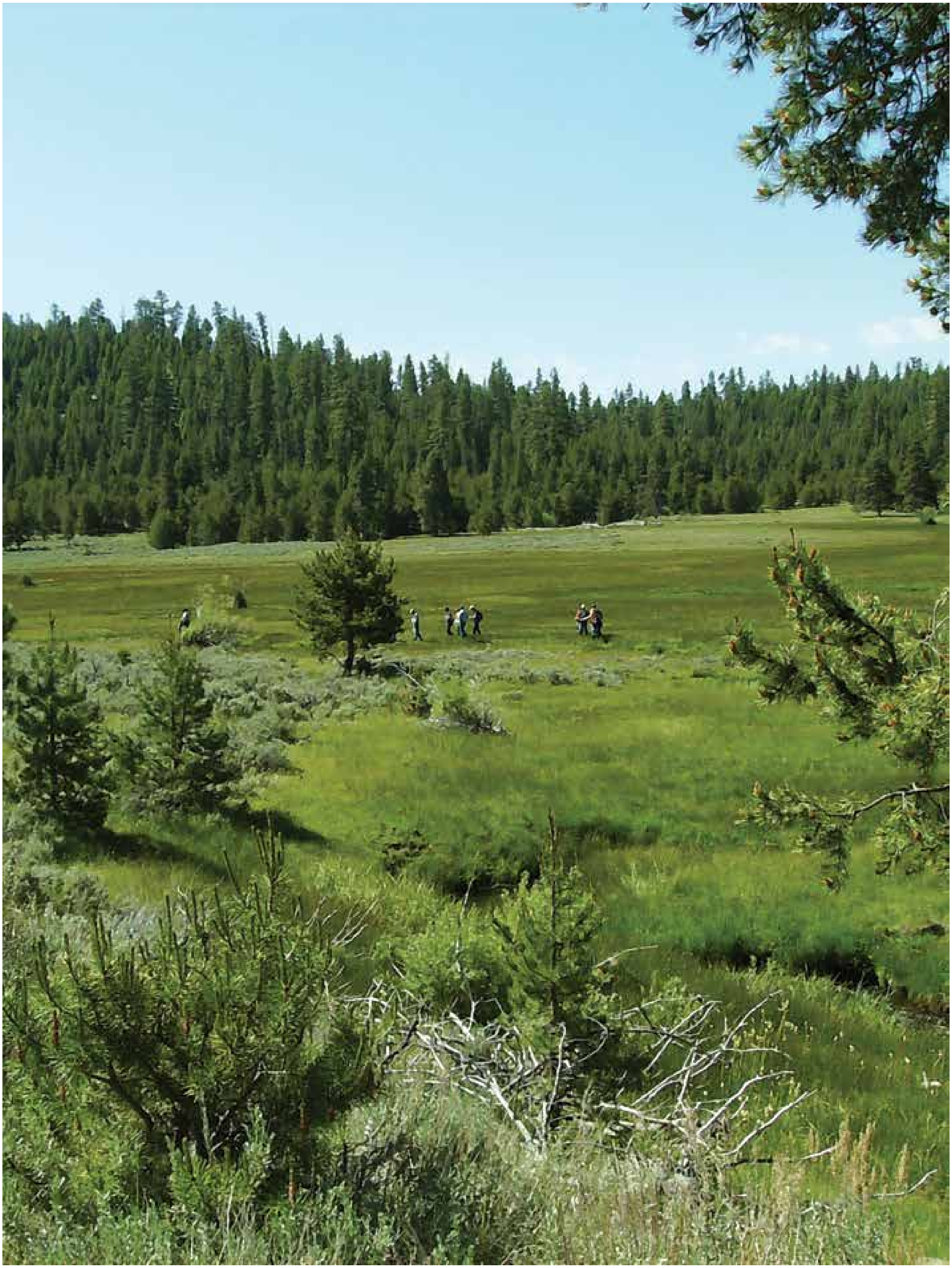
☐ Yes ☐ No

If yes, what are those factors? Check all that apply.

- ☐ Flow regulations
- ☐ Mining activities
- ☐ Upstream channel conditions
- ☐ Channelization
- ☐ Road encroachment
- ☐ Oil field water discharge
- ☐ Augmented flows
- ☐ Other (specify:)

Explain factors preventing achievement of PFC:

(Revised 2014)



Riparian Plant List Form (Lotic) – Instructions

The ID team should record the riparian species found in the reach on the "Riparian Plant List Form." Minor or inconsequential plants do not have to be recorded. Instead, the ID team should note all species that are important to the function of the riparian area, for example, those that colonize stream deposits, provide bank stability, trap sediment, provide shade, or indicate abundance and depth of soil moisture. A detailed riparian plant list includes: a description of the U.S. Army Corps of Engineers plant region, plant symbols, common or scientific name(s) of plants, their relative abundance (column AB), their geomorphic surface (column GS), their wetland indicator category (column WIC), their stability class (column SC), and whether they are nonnative, invasive species (column IN).

U.S. Army Corps of Engineers (USACE) Plant Region

Plant regions in the United States are mapped and delineated on the U.S. Army Corps of Engineers National Wetland Plant List website. The plant regions include:

- Alaska (AK)
- Arid West (AW)
- Atlantic and Gulf Coastal Plain (AGCP)
- Eastern Mountains and Piedmont (EMP)
- Great Plains (GP)
- Hawaii (HI)
- Midwest (MW)
- Northcentral and Northeast (NCNE)
- Western Mountains, Valleys, and Coast (WMVC)

Plant Symbol

Document the plant symbol, as found in the USDA PLANTS Database (USDA-NRCS 2015).

Presence/Relative Abundance (AB)

Document the riparian species observed in the reach to answer item 6 on the PFC assessment form. The ID team may choose to indicate the presence of a plant with a checkmark in the left hand column and then to note the relative abundance of each species observed using a numerical scale of 1 to 4 in the AB column. The scale is not based on plant-cover data collected from quadrats but on a crude visual estimation of the abundance of a species in a given reach:

1 = Species present but with only one to a few individuals found in the reach.

2 = Species found intermittently or occasionally throughout reach.

3 = Species generally common and missing in comparatively small parts of the reach.

4 = Species abundant and found along the entire reach.

Geomorphic Surface (GS)

The location of riparian plants with different wetland indicator statuses helps address item 8 (species present indicate maintenance of riparian soil-moisture characteristics) and item 4 (riparian area is expanding or has achieved potential extent) on the "PFC Assessment Form." The ID team can learn much about the depth to a shallow water table by noting which geomorphic surfaces have hydric plants and which have upland plants. Geomorphic surfaces include active channel (C), streambank (B), floodplain (F), mid-channel bar (MC), point bar (PB), terrace (T). Specify and define other surfaces if needed.

Wetland Indicator Categories (WIC)

The ID team can address item 8 by noting the WIC (Lichvar et al. 2014) of individual species throughout the riparian area. The WICs include obligate wetland (OBL), facultative wetland (FACW), facultative (FAC), facultative upland (FACU), and obligate upland (UPL). See item 8 and the explanation at the end of the riparian plant list for details. The wetland indicator status of plants can change from one region to the next.

Stability Class (SC)

Item 9 asks if the right plants/plant communities (i.e., those with strong, stabilizing root systems) are present to protect streambanks during moderately high flows. A few studies (e.g., Winward 2000) have attempted to quantify the relative rooting strength of common riparian plants. Winward (2000) used a numerical scale from 1 (weakest) to 10 (strongest) to denote relative rooting strength of various community types. However, when ID teams conduct PFC assessments, they are not making the quantified measurements to justify use of highly detailed numerical scales. Also, the plant list typically includes individual species and not community types. Therefore, a broad, three-tiered scale of "low," "medium," and "high" rooting stability is recommended for PFC assessments. These classes approximate Winward's (2000) stability classes of 1-3 for "low," 4-6 for "medium," and 7-10 for "high." The MIM data analysis module (Burton et al. 2011) contains stability classes for most riparian plants in the central and western United States.

Nonnative, Invasive Species (IN)

Although nonnative, invasive species may provide riparian stability, they may not be desirable in terms of habitat or ecological goals. Note whether these species are present.

Lotic PFC Riparian Plant List Form

Riparian area/stream name: Reach ID: Date:

Region (USACE or other):

√	Plant Symbol	Common Name	Scientific Name	AB	GS	WIC	SC	IN
Trees/Shrubs								
Graminoids/Grasses								
Forbs								

Notes:

Explanation Of Plant List

√ Check species present.

Abundance (AB): Use a scale of 1 to 4, with 1 = species is present but with only one to a few individuals in the reach, 2 = species is found occasionally throughout the area, 3 = species is common throughout the area, and 4 = species is ubiquitous throughout the area.

Geomorphic Surface (GS): C= active channel; B = streambank; F = floodplain; MC = mid-channel bar; PB = point bar; T = terrace. **Specify and define others.**

Wetland Indicator Category (WIC): See most recent National Wetland Plant List at *http://wetland_plants.usace.army.mil/*

- **OBL** (obligate wetland plants)—Almost always occur in wetlands.
- **FACW** (facultative wetland plants)—Usually occur in wetlands, but may occur in nonwetlands
- **FAC** (facultative wetland plants)—Occur in wetlands and nonwetlands
- **FACU** (facultative upland plants)—Usually occur in nonwetlands, buy may occur in wetlands
- **UPL** (upland plants)—Almost never occur in wetlands

Stability Class/Rooting Strength (SC): Relative values based on general rooting characteristics assigned by Burton et al. (2011); numerical values conform to Winward (2000).

Forbs

Taproot or most roots, shallow (<15 cm)	Low (2)
Fibrous roots, usually up to 30 cm	Medium (5)
Rhizomatous roots, with 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, cespitose, tufted, or short 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 (<15 cm)	Medium (5)
Root crown with spreading roots	High (8.5)
Widespread root systems	High (8.5)

Nonnative, Invasive Species (IN): Note whether this species is nonnative, invasive species by marking this column.

Photo Documentation

Photographs to support key observations are an important component of PFC assessment documentation. Taking photos at either end of the reach (upstream and downstream), as well at notable features along the reach is recommended. In addition, photos that illustrate or support observations and "yes"/"no" answers on the "PFC Assessment Form" are helpful. Each photograph may have readily apparent meaning to one or more ID team members immediately after the assessment but time, change in personnel, retirements, and poor memories may quickly obscure the location, meaning, and importance of photographs. A brief description of the key feature should be recorded for each photograph. Preferably, the location of photographs will be determined by a global positioning system (GPS) and marked on an attached aerial photograph or topographic map. Storage of GPS photopoints in a GIS will facilitate electronic storage and retrieval of photographs in a reach-by-reach manner.

Appendix B—Quantitative Measures for Assessment Items

The PFC protocol is a qualitative assessment of various attributes and processes. As such, there will be times when items from the assessment need to be quantified. Quantitative techniques are encouraged in conjunction with the PFC assessment for individual calibration where answers are uncertain (to validate a particular assessment item) or where experience is limited. In addition, the use of quantitative techniques is necessary to monitor the change in a particular attribute over time accurately and precisely. Although quantitative techniques can be used to help address most of the assessment items, exclusively observational indicators will be difficult to quantify, such as item 2 (beaver dams are stable) or item 10 (riparian plants exhibit high vigor). The following table provides a summary of techniques that can be used to quantify the assessment items. This list represents the most commonly used and accepted procedures and is by no means an exhaustive list of every technique available for quantifying the attributes. Use of standard monitoring protocols with quantitative indicators that correspond with components of the PFC checklist (such as the MIM; BLM's assessment, inventory, and monitoring (AIM); or PACFISH/INFISH biological opinion (PIBO) protocols), is encouraged. Burton et al. (2011) provide a "PFC Validation Table" in the MIM data analysis module that automatically populates data values into the appropriate assessment items where they can be used for interpretation. The most recent version of this module is available at *http://www.blm.gov/wo/st/en/info/blm-library/publications/blm_publications/tech_refs.html.*

Quantitative Item	Measurement (References)	Interpretation, Notes
Item 1: Floodplain is inundated in "relatively frequent" events.		
Bankfull channel dimensions	Harrelson et al. 1994; Rosgen 1996; USDA Forest Service 2014.	Quantitative measurement of stream channel to determine cross-sectional area and confirm floodplain identification.
Regional curves	Regional curves have been developed for many regions of the country. ID teams should determine whether they have been developed for their region.	Identifies expected bankfull channel dimensions (channel cross-sectional area, bankfull width, bankfull mean depth, and bankfull discharge) for assessed streams based upon drainage area.
Item 2: Beaver dams are stable.		
Repeat photography, aerial photography, and dendrochronology for age-class determination of shrubs and trees rooted on beaver dams can provide information on the longevity and stability of beaver dams.		
Item 3: Sinuosity, gradient, and width/depth ratio are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region).		
Sinuosity	Recent topographic maps; aerial photographs; Rosgen 1996.	Measurement of stream channel to determine actual channel sinuosity.
Gradient	Harrelson et al. 1994; Rosgen 1996; USDA Forest Service 2014.	Determines actual water surface gradient.
Width/depth ratios	Harrelson et al. 1994; Rosgen 1996; USEPA 2009.	Determines actual width/depth ratio.

Quantitative Item	Measurement (References)	Interpretation, Notes
Reference reach	Leopold and Maddock 1953.	The existing channel characteristics of dimension, pattern, and profile are compared to those in a stable channel reach that is the same stream type in similar geology and a similar watershed.
Item 4: Riparian area is expanding or has achieved potential extent.		
Use of remote sensing products (aerial photographs, LIDAR, and satellite imagery)	Clemmer 2001. Imagery products are available from the USDA Farm Service Agency Aerial Photography Field Office.	Map/measure riparian area and channel width changes over time.
Greenline composition	Burton et al. 2011; USDA Forest Service 2014; Winward 2000.	Comparison of different year's data of plant composition on the streambanks (on the greenline) determines if riparian vegetation is expanding along the greenline.
Ecological type identification and ecological status determination	Weixelman et al. 1997.	Analytical method for classifying ecological types for mountain meadows in central Nevada.
Greenline-to-greenline width	Burton et al. 2011.	Nonvegetated distance between greenlines provides an indication of channel narrowing and is correlated with riparian vegetation expanding inward.
Width/depth ratio	Harrelson et al. 1994; Rosgen 1996; USEPA 2009.	The ratio of the bankfull surface width to the mean depth of the bankfull channel. Channel narrowing is correlated with riparian vegetation expanding inward.
Monitoring wells/ piezometers	Cooper and Merritt 2012; Sprecher 2000.	Water level measurements should be taken at least four times a year or more often, if possible. For a greater understanding of the ground-water/ surface-water interactions, streamflow measurements should be made and correlated with fluctuations in ground-water levels in monitoring wells. The most reliable indicator for changes in shallow ground-water conditions supporting riparian vegetation is combining monitoring well measurements in the riparian area with detailed assessments of vegetative health.
Redox potential	Cooper and Merritt 2012.	Redox potential is a measure of the soil oxidation-reduction potential, which can be measured with a millivolt meter.

Quantitative Item	Measurement (References)	Interpretation, Notes
Woody plant age structure	Friedman et al. 1996.	Age structure documents channel narrowing through floodplain development and riparian expansion.
Riparian vegetation cross sections	USDA Forest Service 2014; Winward 2000.	Plot data (USDA Forest Service 2014) and paced transect data (Winward 2000) to quantify plant composition changes across riparian area (to detect riparian area expansion or contraction).
Sampling geomorphic surfaces and riparian vegetation	Scott and Reynolds 2007.	Reach-scale plot data of geomorphic surfaces and associated riparian vegetation to quantify plant composition changes across riparian area (to detect riparian area expansion or contraction).
The above three protocols establish transects perpendicular to the grade in a riparian complex and sample different geomorphic surfaces with differing soil moisture and depth to ground water, and thus require careful interpretation of results.		
Item 5: Riparian impairment from the upstream or upland watershed is absent.		
The same quantitative methodologies listed for item 17 about sediment and water balance would apply here to understand whether the watershed is contributing to riparian impairment, along with methods to measure greenline vegetation listed in item 4.		
Item 6: There is adequate diversity of stabilizing riparian vegetation for recovery/maintenance.		
Greenline composition	Burton et al. 2011; USDA Forest Service 2014.	Plot data of plant composition on the streambanks (on the greenline) to determine if stabilizing riparian species are present.
	Winward 2000.	Paced transect data of plant composition on the streambanks (on the greenline) to determine if stabilizing riparian species are present.
Cross-section composition (vegetation)	Winward 2000; USDA Forest Service 2014.	Paced transect data (Winward 2000) and plot data (USDA Forest Service 2014) to determine if stabilizing riparian species are present across the riparian area.
Item 7: There are adequate age classes of stabilizing riparian vegetation for recovery/maintenance.		
Greenline composition	Burton et al. 2011; USDA Forest Service 2014.	Plot data of plant composition on the streambanks (on the greenline) to help assess herbaceous plant reproduction status.
	Winward 2000.	Paced transect data of plant composition on the streambanks (on the greenline) to help assess herbaceous plant reproduction status.
Riparian vegetation cross sections	Winward 2000; USDA Forest Service 2014.	Paced transect data (Winward 2000 and plot data (USDA Forest Service 2014) to help assess herbaceous plant reproduction status across the riparian area.

Quantitative Item	Measurement (References)	Interpretation, Notes
Woody species height class	Burton et al. 2011.	Used in conjunction with MIM greenline composition, provides metrics to characterize the height of woody plants on/overhanging the greenline.
Woody species age class	Burton et al. 2011.	Plot data to quantify woody age classes on the streambanks (on the greenline).
Woody species regeneration	Winward 2000.	Paced transect data to quantify woody age classes on the streambanks (on the greenline).
Ecological type identification and ecological status determination	Weixelman et al. 1997.	Analytical method for classifying ecological types for mountain meadows in central Nevada.
Item 8: Species present indicate maintenance of riparian soil-moisture characteristics.		
Greenline composition	Burton et al. 2011; USDA Forest Service 2014.	Plot data of plant composition on the streambanks (on the greenline) to determine wetland status.
	Winward 2000.	Paced transect data of plant composition on the streambanks (on the greenline) to help determine wetland status.
Riparian vegetation cross sections	Winward 2000; USDA Forest Service 2014.	Paced transect data (Winward 2000) and plot data (USDA Forest Service 2014) to help determine wetland status across the riparian area.
Ecological type identification and ecological status determination	Weixelman et al. 1997.	Analytical method for classifying ecological types for mountain meadows in central Nevada.
Monitoring wells/ piezometers	Cooper and Merritt 2012; Sprecher 2000.	Water level measurements should be taken at least four times a year or more often, if possible. For a greater understanding of the ground-water/ surface-water interactions, streamflow measurements should be made and correlated with fluctuations in ground-water levels in monitoring wells. The most reliable indicator for changes in shallow ground-water conditions supporting riparian vegetation is combining monitoring well measurements in the riparian area with detailed assessments of vegetative health.

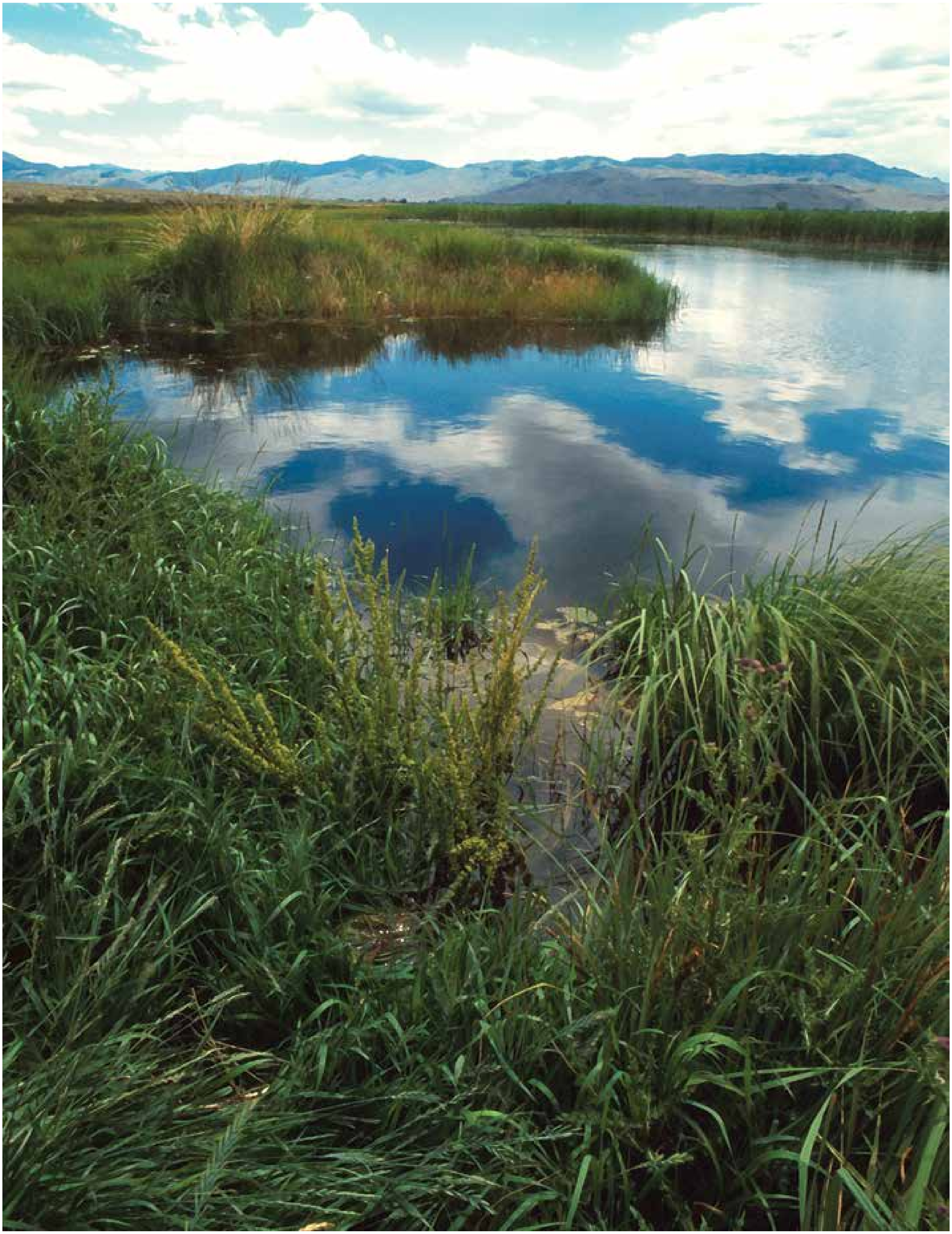
Quantitative Item	Measurement (References)	Interpretation, Notes
Item 9: Stabilizing plant communities capable of withstanding moderately high streamflow events are present along the streambank.		
Greenline composition	Burton et al. 2011; USDA Forest Service 2014.	Plot data of plant composition on the streambanks (on the greenline) to determine if stabilizing riparian species are present.
	Winward 2000.	Paced transect data of plant composition on the streambanks (on the greenline) to determine if stabilizing riparian species are present.
Item 10: Riparian plants exhibit high vigor.		
Vigor is qualitative and must be observed in the field.		
Item 11: An adequate amount of stabilizing riparian vegetation is present to protect banks and dissipate energy during moderately high flows.		
Greenline composition	Burton et al. 2011; USDA Forest Service 2014.	Plot data of plant composition on the streambanks (on the greenline) to determine if enough stabilizing riparian species are present. Burton et al. (2011) provide a metric for greenline stability rating (vegetation erosion resistance).
	Winward 2000.	Paced transect data of plant composition on the streambanks (on the greenline) to determine if enough stabilizing riparian species are present. Provides data for greenline stability rating (vegetation erosion resistance).
Streambank stability and cover	Burton et al. 2011; USDA Forest Service 2014.	Plot data metrics provide average streambank stability and cover to help determine if present vegetation is providing stability.
Item 12: Plant communities are an adequate source of woody material for maintenance/recovery.		
Greenline composition	Burton et al. 2011; USDA Forest Service 2014.	Plot data of plant composition on the streambanks (on the greenline) to quantify woody vegetation.
	Winward 2000.	Paced transect data of plant composition on the streambanks (on the greenline) to quantify woody vegetation.
Woody species height class	Burton et al. 2011.	Used in conjunction with MIM greenline composition, provides metrics to characterize the height of woody plants on/overhanging the greenline.
Woody species age class	Burton et al. 2011.	Plot data to quantify woody age classes on the streambanks (on the greenline).
Woody species regeneration	Winward 2000.	Paced transect data to quantify woody age classes on the streambanks (on the greenline).

Quantitative Item	Measurement (References)	Interpretation, Notes
Riparian vegetation cross sections	Winward 2000; USDA Forest Service 2014.	Paced transect data (Winward 2000) and plot data (USDA Forest Service 2014) to help quantify woody vegetation across the riparian area.
Item 13: Floodplain and channel characteristics (i.e., rocks, woody material, vegetation, floodplain size, overflow channels) are adequate to dissipate energy.		
Stream classification	Montgomery and Buffington 1993, 1997; Rosgen 1994, 1996.	Identifies whether the listed floodplain and channel characteristics are a part of the stream type being assessed.
Large woody material counts	Davis et al. 2003; USDA Forest Service 2014; USEPA 2009; Wohl et al. 2010.	Quantifies the number and size of large woody material.
Range of meander width ratio (belt width/ bankfull width) by stream type	Harman et al. 2012; Rosgen 1996 (pp. 4-9 and chapters on level III and level IV).	Compares measured values against expected values for different stream types.
Manning's *n*, computer models such as Hydrologic Engineering Centers River Analysis System (HEC-RAS)	Federal Interagency Stream Restoration Working Group 1998 (pp. 7-19).	Manning's *n* values are computed for a reach in which multiple cross sections and water surface elevations and at least one discharge have been measured. A series of water surface profiles are then computed with different *n* values, and the computed profile that matches the measured profile is deemed to have an *n* value that most nearly represents the roughness of that stream reach at the specific discharge.
Item 14: Point bars are revegetating with stabilizing riparian plants.		
If quantitative methodologies are required, consult the measurement of vegetation composition discussed under item 7 and consult the estimation of bank stability discussed under item 9. Vegetation monitoring methods typically evaluate conditions throughout a DMA and do not make targeted measurements on point bars exclusively.		
Item 15: Streambanks are laterally stable.		
Lateral stream movement	Rosgen 1996.	Bank erosion pins. Annual measurements should be related to magnitude and duration of high-flow events.
	Harrelson et al. 1994.	Monumented channel cross section where bank erosion is high (i.e., more than a few feet per year).
	Clemmer 2001; Prichard et al. 1996.	Comparison of series of aerial photos covering several years or decades to identify channel adjustments through time.
Channel migration rates	Everitt 1968; Nanson and Hicken 1983.	Dendrochronology where riparian trees and shrubs establish on point-bar or natural levee deposits.

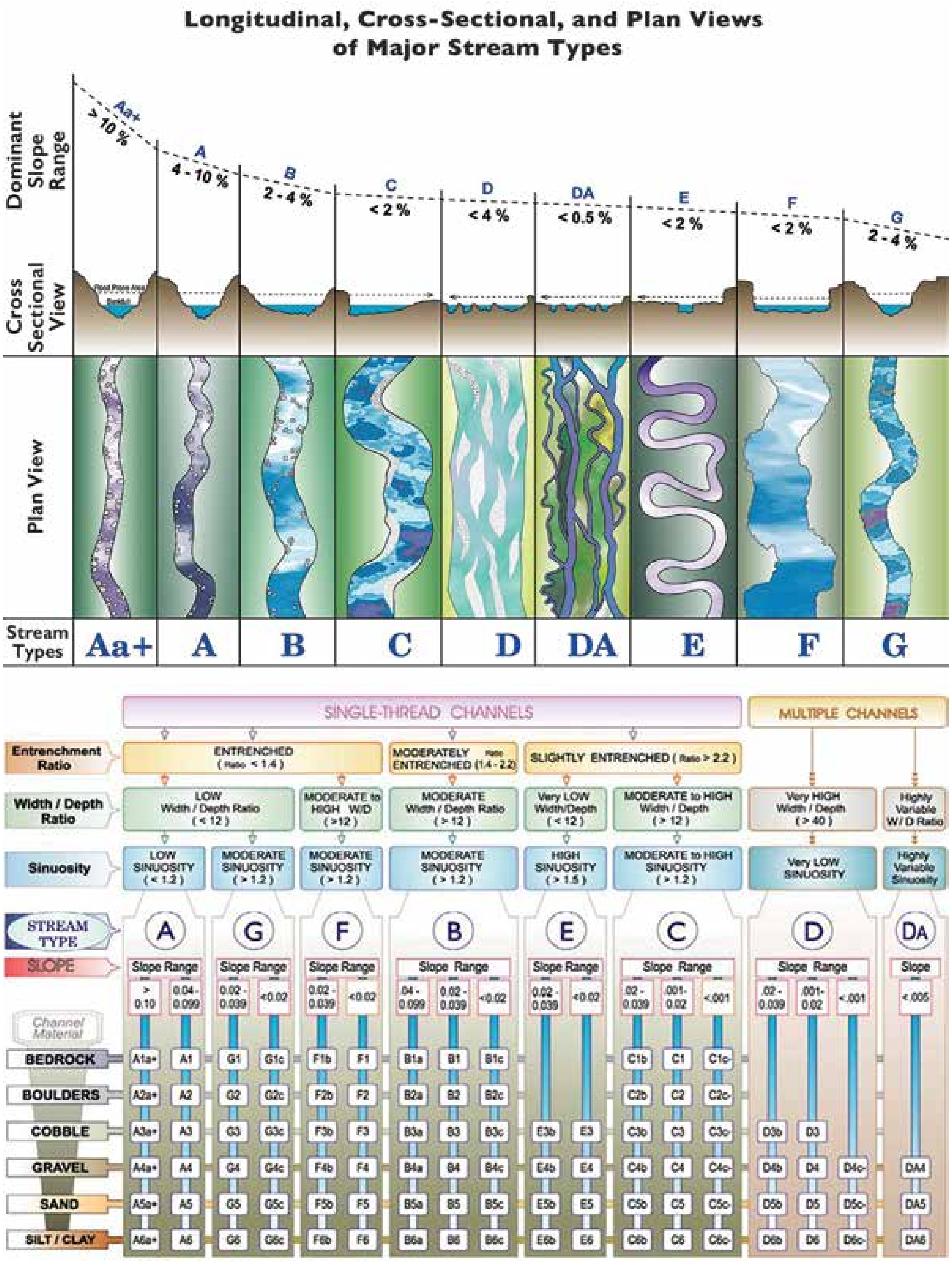
Quantitative Item	Measurement (References)	Interpretation, Notes
Bank stability	Burton et al. 2011.	Bank alteration, bank stability measurements, and greenline-to-greenline width provide clues to channel processes that affect lateral stability.
In some cases, erosion rates may remain low for a period of years until some threshold of flow is exceeded, after which erosion may increase by one or more orders of magnitude. Therefore, the ID team should obtain a record of the duration and magnitude of high flows sufficient to initiate lateral movement of the channel.		
Item 16: Stream system is vertically stable (not incising).		
Vertical stream movement	Harrelson et al. 1994; USEPA 2009.	Monumented channel cross section using a stable reference point as a permanent benchmark (Harrelson et al. 1994), or temporary cross sections (USEPA 2009) to measure channel dimensions.
	Clemmer 2001; Prichard et al. 1996.	Comparison of series of aerial photos covering several years or decades to identify knickpoint migration and identify channel adjustments through time.
	Gonzalez 2001a, 2001b.	Dendochronology is used to compare the age of the oldest tree (or shrub) on the inset floodplain or channel and the age of the youngest tree (or shrub) on the adjacent terrace (abandoned floodplain or channel) to constrain the date of incision, determine the rate of headcut propagation upstream, or determine if channel incision has ceased or is continuing.
Item 17: Stream is in balance with the water and sediment that is being supplied by the drainage basin (i.e., no excessive erosion or deposition).		
Stream classification	Rosgen (level IV) 1994, 1996; Montgomery and Buffington 1993, 1997.	Stream classification provides a consistent and semiquantitative means for describing and comparing geomorphic characteristics of channels (Dorava et al. 2001). The sequence of stream types can reveal systemwide instabilities (Federal Interagency Stream Restoration Working Group 1998).
Compare channel surveys (longitudinal and cross section)	Federal Interagency Stream Restoration Working Group 1998 (pp. 7-53); Harrelson et al. 1994.	Document changes in channel cross section and longitudinal profile of thalweg; water-surface gradient; bankfull gradient; and floodplain, valley, or terrace gradients. Surveys are completed at permanent monitoring sites.

Quantitative Item	Measurement (References)	Interpretation, Notes
Geomorphic studies and assessments	Thorne 1998; Rosgen 1996.	Detailed geomorphic studies require trained geomorphologists with ample field experience. Studies historical documents, floodplain deposits, and characteristics of abandoned channels. Examines channel, floodplain, and valley characteristics. Requires an understanding of streambank erosion processes and channel-forming processes.
Watershed Assessment of River Stability and Sediment Supply (WARSSS), POWERSED, and FLOWSED	Rosgen 2006a, 2006b; *http://water.epa.gov/scitech/datait/tools/warsss/index.cfm*.	WARSSS is a three-phase technical framework of methods for assessing suspended and bedload sediment in rivers and streams. It is a watershed approach to sediment assessment that focuses on natural variability in sediment dynamics, geologic versus anthropogenic sediment sources, erosional and depositional processes, prediction of sediment loads, streamflow changes, and stream channel stability and departure from reference condition. POWERSED and FLOWSED models predict changes in incision or aggradation processes associated with impaired streams.
Schumm's F versus M relationship $F=255\ M^{-1.08}$	Federal Interagency Stream Restoration Working Group 1998 (pp. 7-38).	Channel width/depth ratio (F) at mean annual discharge and the percent of silt and clay in the channel boundary (M) are useful diagnostics for determining systemwide adjustments.
Aerial photograph sequence, evaluation of channel adjustments	Clemmer 2001; Prichard et al. 1996.	Review aerial photographs over time.
Scour chains	Harrelson et al. 1994.	Scour chains may be used to measure the aggradation or incision of the streambed.
Pebble counts	Burton et al. 2011; Bunte and Abt 2001; Kerschner et al. 2004; Davis et al. 2003; Bevenger and King 1995.	Determines surface substrate size distribution and percent fines.
Residual pool depth	Burton et al. 2011; Kaufmann et al. 2008; Keim and Skaugset 2002; USDA Forest Service 2014.	Pools may fill with sediment associated with a higher sediment load in the channel; a higher width/depth ratio often is caused by a decrease in the ability of the stream to scour the bed. Maximum (thalweg) depth decreases over time indicate pools filling with sediment.

Quantitative Item	Measurement (References)	Interpretation, Notes
Relative bed stability	Stoddard et al. 2005; Kaufmann et al. 2008; Robison 1998.	Ratio comparing the particle size of observed sediments to the size sediment each stream can move or scour during its flood stage, based on the size, slope, and other physical characteristics of the stream channel. Kaufmann et al. (2008) measure streambed textural "fining" that occurs as a response to increases in the rate of upland erosion and the increased mobility or instability of the bed substrate that accompanies such inputs of fine-textured substrates.
Geomorphic history using streamgage discharge measurements that include physical measurements of the channel; specific gage analysis	Smelser and Schmidt 1998; Federal Interagency Stream Restoration Working Group 1998.	History of channel adjustment is compared to histories of climate change, flow regulation, and land use to link geomorphic adjustments to particular patterns, events, or activities. A channel is considered to be in equilibrium if the specific gage record shows no consistent increasing or decreasing of trends over time.
Indicators of Hydrologic Alteration (IHA) software package (Smythe Scientific Software)	Richter et al. 1996.	A suite of 33 hydrologic parameters that are ecologically meaningful and serve as sensitive indicators of anthropogenic effects on riverine systems. The software calculates the parameters by using daily streamflow data obtained from USGS.



Appendix C—Rosgen Classification System (Rosgen 1977)



Longitudinal, Cross-Sectional, and Plan Views of Major Stream Types

KEY to the ROSGEN CLASSIFICATION of NATURAL RIVERS. As a function of the "*continuum of physical variables*" within stream reaches, values of **Entrenchment** and **Sinuosity** ratios can vary by +/- 0.2 units, whiles values for **Width / Depth** ratios can vary by +/- 2.0 units.

Appendix D—Applying Potential to Human-Altered Stream Reaches

Example 1: Great Basin, channelized intermittent stream with hardened banks

1. Are alterations creating artificial channel conditions for a substantial part of the reach?

Yes. This reach has been straightened and permanently channelized with hardened banks (revetment material) to protect the road. This channel is not expected to be further modified or rerouted in the near future. A PFC assessment would not be completed on this reach at present as it is not expected to function as a natural stream.

2. Are alterations present but the potential of the reach remains unchanged?

Not applicable. A PFC assessment would not be done on this reach.

3. Are alterations present that have changed the potential of the reach (but have not created artificial channel conditions for a substantial part of the reach)?

Not applicable. A PFC assessment would not be done on this reach.

Example 2: Northern Rocky Mountains, dewatered stream with upstream diversion

1. Are alterations creating artificial channel conditions for a substantial part of the reach?

Yes. An upstream diversion has changed this stream reach from perennial to ephemeral. Black cottonwood and coyote willow are present; however, both are facultative species in this region. This diversion is not expected to be removed in the near future. A PFC assessment would not be completed on this reach at present as it is not expected to function as a natural perennial or intermittent stream. Additionally, because the reach is now ephemeral and the PFC assessment is designed for perennial and intermittent streams, this reach would not be assessed for PFC.

2. Are alterations present but the potential of the reach remains unchanged?

Not applicable. A PFC assessment would not be done on this reach.

3. Are alterations present that have changed the potential of the reach (but have not created artificial channel conditions for a substantial part of the reach)?

Not applicable. A PFC assessment would not be done on this reach.

Example 3: Colorado Plateau, perennial stream with earthen dam upstream

1. Are alterations creating artificial channel conditions for a substantial part of the reach?

No. Although the streamflows are highly regulated, the channel can still produce attributes that will allow the stream to function properly; therefore, a PFC assessment would be completed.

2. Are alterations present but the potential of the reach remains unchanged?

No. The potential has been changed.

3. Are alterations present that have changed the potential of the reach (but have not created artificial channel conditions for a substantial part of the reach)?

Yes. The altered potential will now be used as the basis for determining which attributes and processes are needed for PFC.

An upstream dam has altered the potential of this reach. Prior to installation of an upstream dam in the 1920s for irrigation storage, indications are that this reach was an E4 stream type dominated by a mix of sedge-rush and willow communities with a considerably wider floodplain than currently exists. Flow regulation has reduced the timing and magnitude of floodflows and the channel is nearly dewatered from November to April during many years. As a result, the floodplain area is reduced, the width of the riparian area has decreased, and vegetation communities have changed.

The dam and flow regulation are not expected to change. The potential of this reach is still an E stream type; however, the potential floodplain width and corresponding riparian area are narrower than they were historically. Because overbank flows and depositional events are rare, willow reproduction has been essentially eliminated. The new potential vegetation is exclusively sedge-rush communities along the streambank with mesic graminoid-forb communities away from the channel. Stabilizing wetland vegetation is still needed, and the right species may or may not be present, vigorous, reproducing, and adequate.

Appendix E—Example Assessments

The examples provided here were selected to provide a range of assessment conditions (from PFC to NF) as well as a range of stream types (intermittent and perennial) in different physiographic settings (mid-elevation, moderate- to high-gradient forested mountains to low-gradient, prairie-style Great Plains). Three types of examples are included.

The first set of examples show a variety of conditions and locations:

- A perennial stream in the Northern Rocky Mountains with a willow/sedge community (two reaches to show PFC and FAR).
- A perennial stream in the Great Basin with a potential willow-sedge community (NF).
- A perennial stream in the Blue Mountains on the Columbia Plateau with a sedge/rush community (FAR).

The second set of examples shows the recovery of two streams (Rocky Mountain and Wyoming Basin), and discusses the corresponding changes to condition.

The last example is a detailed and fairly comprehensive writeup on a Great Plains intermittent stream with high-alkalinity limitations to its potential. This example illustrates the types of information assembled and used by an ID team to develop a model of potential from which to interpret field conditions.

Condition Examples

Perennial Stream, Northern Rocky Mountains

Two reaches along the same stream are summarized in this example. Reach 1 was determined to be relatively close to its ecological potential. This determination was useful for assessing reach 2, which clearly represents a departure from potential.

Potential: This stream has the potential to be a sinuous, low-gradient E stream type with a gravel-dominated streambed flowing through a wide, unconfined valley bottom. The stream is in a snowmelt-dominated system with a drainage area of 22 square miles. The riparian plant community should be a willow/sedge type dominated by Drummond's and Lemmon's willow (both important for bank stability on this stream) and both water sedge and beaked sedge. This stream downcut and widened approximately 0.5 meters about 30 years ago.

Reach 1: Proper functioning condition

Rating and Key Factors: Reach 1 is rated as PFC because all assessment items were answered "yes" and the reach has adequate vegetation to dissipate energy and meet the comprehensive definition of PFC. Not only is this reach in PFC, it is very near potential. This reach has clearly recovered from the past channel incision as willows and other riparian stabilizers have become reestablished and the channel has narrowed. The channel has adequate floodplain connectivity, the channel shape is appropriate for the landscape setting, and multiple species and age classes of vigorous riparian stabilizers are present. Although there is some streambank instability present on some outside meander bends in the form of slump blocks, it is limited in extent. It is not uncommon for streams to exhibit some streambank instability at PFC or even at potential.

Reach 2: Functional–at risk with a downward trend

Rating and Key Factors: Reach 2 is rated as FAR due to a number of factors that make it susceptible to impairment. It is clear that this reach has not recovered from past channel incision and widening. Because the stream is entrenched and has a higher width/depth ratio than expected, too much energy is confined within the channel and moderately high flows are unable to spread out over a broad floodplain (loss of floodplain connectivity). The historic floodplain is inaccessible and has become a terrace. For these reasons, items 1 and 3 were answered "no." Streambank vegetation is primarily shallow-rooted mesic graminoids, and the reach lacks a willow component—a key attribute for function on this stream. As a result, there is not adequate stabilizing vegetative cover to dissipate energy during high-flow events (item 11). Slump blocks have formed on most all erosional banks causing overall streambank stability to be low. Trend on this reach was determined using monitoring data (monitored trend) that clearly indicated a decline in several key attributes.

Perennial Stream, Basin and Range, Great Basin

Nonfunctional

Reference Reach

Potential: This reach has the potential to be a low-gradient C stream type (meandering channel with riffle-pool streambed features) with a sand- and silt-clay-dominated streambed. The stream is in a primarily snowmelt-dominated system with a drainage area of 150 square miles. The riparian plant community should be a willow/sedge type dominated by coyote and yellow willow and both Nebraska and beaked sedge. As shown in the properly functioning reference reach in the lower right photo (which is located on the same stream system), these systems commonly recover and evolve by forming an inset floodplain at a new base elevation. As they recover, vegetation becomes established on the new floodplain and on the streambanks and the channel narrows.

Rating and Key Factors: This stream is rated as NF as it is clearly not providing adequate vegetation, landform, or woody material to dissipate stream energy. The lack of a well-developed channel and a high width/depth ratio are evident. Most of the items on the assessment form were answered "no." One exception was item 8, which was answered "yes" because spikerush is the most dominant riparian plant on this reach and it is a pioneering obligate wetland plant, so it is clear that riparian soil moisture characteristics are being maintained. Identifying this factor is key because although this reach is NF, the presence of soil moisture would allow this stream reach to recover relatively quickly and begin to exhibit the attributes of the reference reach.

Perennial Stream, Columbia Plateau, Blue Mountains

Functional–at risk with a downward trend

Potential: This stream reach has the potential to be a low-gradient, meandering C stream type with a gravel-dominated streambed flowing through a gentle gradient alluvial canyon. Bankfull events can result from short rainfall-induced events to longer snowmelt-induced events, and the drainage area is 36 square miles. The riparian plant communities should be willow-dominated thickets along the stream in mosaics with sedges and rushes.

Rating and Key Factors: This stream reach is rated FAR with a downward trend because of the overwidened, dish-shaped channel and bank instability caused by a lack of stabilizing riparian vegetation (estimated at only 20 percent cover). Herbaceous stabilizers show little or no recruitment of young plants. There are multiple age classes of alder, but young shrubs and trees show evidence of repeated browsing as indicated by a "clubbed" growth form. Point bars are not vegetating. Without a well-vegetated riparian area to attenuate streamflow, excessive erosion of streambanks continues at most meander bends. The riparian area has the species composition that would support recovery under changed management.

Recovery Examples

Rocky Mountain, Wyoming Basin, Perennial Stream 1

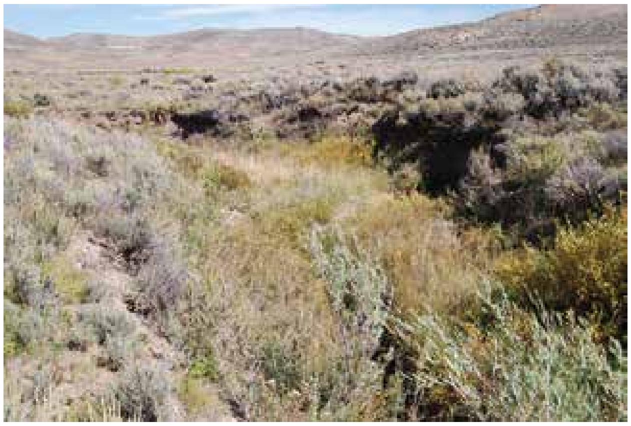
This Wyoming Basin perennial stream has continued to recover, with a change in grazing management, to PFC.

Potential: The ID team determined that this reach has the potential to be a sinuous, low-gradient C stream type with a fine-grain-dominated streambed flowing through an unconfined valley bottom. The stream is in a snowmelt-dominated system with a drainage area of 15 square miles. The riparian plant community should be a willow/sedge type dominated by yellow willow, Nebraska and beaked sedge, and Baltic rush. Due to entrenchment, the stream reach had a narrow floodplain, but increased sinuosity and channel narrowing have provided conditions for recovery.

Rating and Key Factors: This stream was rated FAR with an upward trend in 1989. Recovery continues as adequate riparian vegetation dissipates energy, allowing the floodplain to rebuild and the stream to access the floodplain. Management continues to allow for recovery, and the stream has reached PFC. Continued floodplain recovery is necessary to achieve PNC. Trend monitoring was implemented to document improvement.

FAR, upward trend (1989)

PFC (2013)



Rocky Mountain, Wyoming Basin, Perennial Stream 2

This perennial stream reach has improved to PFC with a change in management since 1983.

Potential: This stream reach has the potential to be a sinuous, moderate-gradient C stream type in a narrow, landform-confined valley bottom. The stream is part of a snowmelt system with a drainage area of 8 square miles. The expected vegetation includes willow/sedge type dominated by yellow willow and Nebraska and beaked sedge.

Rating and Key Factors: This stream reach was rated FAR with no apparent trend in 1983 and since then has recovered to PFC. The key attributes are willows and sedges and access to the floodplain that provide for energy dissipation and stream channel narrowing. Trend monitoring provided information to determine that the attributes in PFC assessment items 1, 3, and 11 had recovered sufficiently to provide a PFC rating, with continued progression towards PNC.

FAR, trend not apparent (1983)

PFC (2006)

PFC (2012)

Detailed Example

Great Plains, Intermittent

This example was modified from a real assessment. The date, location, and names have been altered to preserve the privacy of individuals involved in the assessment. Three separate forms for lotic systems are included:

1. The "Reach Information Form."
2. The "PFC Assessment Form."
3. The "Riparian Plant List Form."

The complete photo log for the reach has been omitted from this example and replaced with only a handful of representative photos with captions. PFC assessments are not intended to be completed using only photos, which may portray local site conditions, not entire reach conditions. The photos are meant to be illustrative of and supportive of observations recorded on the PFC assessment form; they do not constitute representative conditions by themselves.

GIS, GPS, literature, and photographic data are incorporated into the reach information form. Preassessment information, gathered from range files and specialists' reports, provides background information on hydrology, range infrastructure, ecological site descriptions, riparian vegetation, and allotment management. Preassessment materials, along with specialists' knowledge of similar reference reaches, permitted the ID team to describe potential natural conditions.

Reach Information Form (Lotic)

I. Background information:

Date: 07/01/2014

Riparian area/stream name: Specimen Creek

Reach ID: R1-BSNF-SPCR-08

Management unit (allotment/pasture, other): Exemplar Allot/SW Pasture

Administrative unit/state: Big Sky NF

ID team members: Crystal Waters (hydrology), Sandy Plains (range), Robin Vogelsong (wildlife), Curly Dock (botany/ecology), Pete Moss (soils/geomorphology); also Buck and Kittie Hereford (permittees) for the morning.

Assessment method:

Reach length (miles/km): 23 miles

☑ Complete reconnaissance

☐ Selective inspection of representative areas

☐ Remote imagery with selective ground inspection

Location: Attach aerial image, USGS 7.5-minute topographic map, or GIS map with reach breaks indicated.
see photo 1

II. Reach break location:

Reach starting point (upstream)	Reach ending point (downstream)
XX.12345678 N. Lat. UTM E _______ m	XX.12345678 N. Lat. UTM E _______ m
or	or
-YZ.12345678 W. Long. N _______ m	-YZ.12345678 W. Long. N _______ m

Positions by GPS? ☐ Yes ☐ No Photos taken? ☑ Yes ☐ No UTM Zone: ________

Datum: ☐ NAD27 ☑ NAD83 ☐ WGS84 ☐ Other (specify): ________

Rationale for reach breaks: Starting and ending points of reach coincide with pasture (upstream) and allotment (downstream) boundary fences.

III. Description of potential and rationale

(should include description of hydrologic regime, stream type(s), and riparian plant communities at potential; may include additional information such as valley type, gradient, entrenchment ratio, sinuosity, width/depth ratio, and bed and bank materials):

Specimen Creek is an intermittent stream on the ™wet∫ end of the spectrum of intermittent streams. Although streamflow disappears from the channel by mid-summer, moisture is available in most years during the entire growing season from a shallow alluvial aquifer just below the channel along most of the reach. Bedrock geology influences ground-water discharge, which supports short (<200-yard) intervals of perennial flow within the reach.

This reach extends through an unconfined, wide valley bottom with a highly sinuous, meandering channel, prominent point bars, and a pool-and-riffle channel sequence (characteristics of a Rosgen C5 stream type). The channel bed should contain mostly sand with gravel (which promotes pool-riffle sequence), and floodplain is constructed by fine-textured (silt and clay) deposits. Soils and shallow ground water are high in alkalinity, which strongly influences potential vegetation. Alkaline material accumulates in soils, particularly in the capillary zone.

Vegetation info: At potential, the riparian plant community on the streambanks should be dominated by a herbaceous community of common threesquare bulrush (see photos 2a-2c; see Hansen et al. 1995, pp. 462-464). Other alkaline-tolerant, hydric species (inland saltgrass, Baltic rush, foxtail barley, Nuttall's alkaligrass, prairie and alkali cordgrasses) should be common on the streambanks. Patches or linear galleries of riparian cottonwood trees with scattered patches of coyote willow should occur on the point bars and floodplain along with FAC-FACU grasses (western wheatgrass, Canada wildrye), which cannot access the seasonlong supply of water from the shallow alluvial aquifer like deeper rooted shrubs and trees can. The riparian woody species are not required for function in this system, but they establish episodically when overbank flooding, deposition, seed release, and adequate summertime precipitation coincide and permit recruitment of a new cohort of woody riparian plants.

Hydrologic info: Overbank flood events should be common (more or less annual). Peak discharges may occur in the spring from snowmelt or more commonly from overland flow associated with intense, summer thunderstorms. The gradient averages 1.3% (measured by GIS over entire reach from orthophotoquads); the drainage area at the top of the reach is ~30 mi^2; Q1.5 ~175-200 cfs, and estimated cross-sectional area at bankfull is 30 ± 5 ft^2 (from USGS (1992) regional flood curve).

IV. Other assessment or monitoring data or information about the reach:

Rangeland/grazing management notes have been collected in the range administrative files since 1951.

Geomorphology, dendrochronology, and historic precipitation data were summarized in Gonzalez (2001a, 2001b). Part of the contributing drainage basin (about 15-20%) burned 6 years ago (in September 2008 in the Specimen Fire (see ™Specimen Fire--Burned Area Emergency Response∫ report). The fire severity was greatest on north-facing slopes in stands of Rocky Mountain juniper. This reach has had no prior PFC assessments or riparian monitoring data.

This reach is within an 8,900-acre, four-pasture allotment with a deferred-rotation grazing system. Allotment turnout averages May 15 and the season ends Oct. 31 or frequently earlier due to early snow or summer drought. There are 300 cow-calf pairs for 5.5 months for roughly 1,650 AUMs and an approximate stocking rate of 5.4 acres/AUM. The allotment has 1 dam, 13 dugouts on low-order tributaries, and 2 wells that supply 8 upland stock tanks (4 frost free) with 3.5 miles of pipeline. The SW pasture has 3 dugouts and 2 stock tanks (1 frost free). Infrastructure details can be found in the range files.

PFC Assessment Form (Lotic)

Riparian area/stream name: Specimen Creek Reach ID: R1-BSNF-SPCR-08 Date: 07/01/2014

<table>
<tr><th>Yes</th><th>No</th><th>NA</th><th>HYDROLOGY</th></tr>
<tr><td>√</td><td></td><td></td><td>1) Floodplain is inundated in "relatively frequent" events.</td></tr>
<tr><td colspan="4">Rationale: Frequent overbank events are recorded by thin layers of silt and clay deposition on the floodplain and plant materials (twigs, seeds, berries, leaves) piled on upstream side of riparian tree trunks and shrubs. Careful inspection of the plant materials indicates they have accumulated over several years as older, oxidized material is mixed in with fresher, less decomposed plant matter. Recent flood debris and sediment have bent vegetation in the direction of flow across the floodplain (see photo 3).</td></tr>
<tr><td></td><td>√</td><td></td><td>2) Beaver dams are stable.</td></tr>
<tr><td colspan="4">Rationale: Beavers have recently (past 5 years?) moved into this drainage. The low-head dams are all made of mud and small-caliber material, and bank breaches around dams are not uncommon (see photo 4). The dams appear to be constructed rapidly and are likely easily destroyed by high flows. The hydrologic effects from dam failures are likely small because the volume of water stored and the vertical head of ponded water are fairly small. We do not expect the dams to persist if vegetation cannot colonize and stabilize them.</td></tr>
<tr><td></td><td>√</td><td></td><td>3) Sinuosity, gradient, and width/depth ratio are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region).</td></tr>
<tr><td colspan="4">Rationale: Sinuosity (~15; see photo 1) and gradient (13%) appear to be in balance, but width/depth ratio is high. Channel dimensions (note low width/depth ratio) from nearby reference reaches (see photo 2b) are contrasted with channel dimensions (note high width/depth ratio) from this reach (photo 5). Climate, topography, drainage area, channel gradient, geology, hydrology, and potential of this and the reference reach are similar.</td></tr>
<tr><td></td><td>√</td><td></td><td>4) Riparian area is expanding or has achieved potential extent.</td></tr>
<tr><td colspan="4">Rationale: The herbaceous riparian vegetation (obligate wetland and facultative wetland plants) has contracted to a very narrow band on the lower streambank. Bare ground or upland species occur where riparian vegetation is expected (contrast the streambank vegetation cover at reference sites photos 2a-2c with that in photos 4, 5, and 6). The paucity of riparian vegetation on the streambanks (discussed under item 11) means there is diminished opportunity to trap sediment (see photo 2c), build new streambanks, and expand the riparian area inward by narrowing the channel (as is evident in photo 2b).</td></tr>
<tr><td></td><td>√</td><td></td><td>5) Riparian impairment from the upstream or upland watershed is absent.</td></tr>
<tr><td colspan="4">Rationale: In comparison to other similar reaches that are properly functioning, this reach appears to have excessive sediment delivered to Specimen Creek. Many tributary mouths with Specimen Creek have an oversized fan and mid-channel bars have formed downstream of many confluences. Point bars routinely receive thick deposits of sediment in the waning stage of flow only to have much of this sediment remobilized during the next high-flow event (see photo 6). Also, the overly wide channel (see item 3) suggests it has recently been trying to accommodate larger peak flows than occurred previously. The ID team needs to study upland conditions in greater detail to determine the relative sediment contributions from three potential sources, including (1) roadbed and ditches from a stream-parallel road, (2) postfire erosion (Specimen Fire burned about 1,400-1,800 acres in the watershed 6 years ago in fall 2008), and (3) scattered upland sites (particularly blue grama flats with evident rilling and surface flow channels) that are grazed heavily every year (see range 2210 files and the annual use-pattern maps).</td></tr>
</table>

<table>
<tr><th>Yes</th><th>No</th><th>NA</th><th>VEGETATION</th></tr>
<tr><td>✓</td><td></td><td></td><td>6) There is adequate diversity of stabilizing riparian vegetation for recovery/maintenance.</td></tr>
<tr><td colspan="4">Rationale: Riparian stabilizers are found in the reach (see riparian plant list, column SC for plants rated H, high stability). Notable high stabilizers include: common threesquare bulrush, woolly and Nebraska sedges, plains cottonwood, chokecherry, Baltic rush, American mannagrass, prairie cordgrass.</td></tr>
<tr><td>✓</td><td></td><td></td><td>7) There are adequate age classes of stabilizing riparian vegetation for recovery/maintenance.</td></tr>
<tr><td colspan="4">Rationale: Herbaceous riparian plants show evidence of reproduction and rhizomatous propagation in some places, though it is not occurring everywhere (see additional discussion under item 11). Woody riparian plants of multiple age groups are located on the floodplain. Although recruitment is occurring for woody riparian plants, the herbaceous riparian species are the most critical in this system for stability and function.</td></tr>
<tr><td>✓</td><td></td><td></td><td>8) Species present indicate maintenance of riparian soil-moisture characteristics.</td></tr>
<tr><td colspan="4">Rationale: In an intermittent system with moisture available in the subsurface throughout the growing season, we expect to see a mix of obligate and facultative wetland plants as well as some facultative plants on streambanks. We found a diverse mixture of obligate and facultative wetland plants and facultative plants on the streambank (see riparian plant list, column WIS for obligate wetland, facultative wetland, and facultative plants). Notable obligate wetland and facultative wetland plants in this reach include coyote willow, Nebraska and woolly sedges, common threesquare and panicled bulrushes, American mannagrass, foxtail barley, alkali muhly, Nuttall's alkaligrass, and alkali and prairie cordgrasses.</td></tr>
<tr><td>✓</td><td></td><td></td><td>9) Stabilizing plant communities capable of withstanding moderately high streamflow events are present along the streambank.</td></tr>
<tr><td colspan="4">Rationale: This is a weak yes, as we do find riparian, herbaceous, stabilizing species (e.g., common threesquare bulrush, Nebraska sedge, and alkali cordgrass; see plant list, column SC for plants rated H) that have grown into some swards along the streambank; however, the swards occur in small and discontinuous patches. Swards of bulrush can be seen as green patches along the water's edge in photo 5 and on the right water's edge of photo 6. In contrast, individual plants, rather than communities, typify the streambank shown in photo 4, and bare ground is the rule on the left bank of photo 6, indicating that development of plant communities along the streambanks is patchy and discontinuous.</td></tr>
<tr><td></td><td>✓</td><td></td><td>10) Riparian plants exhibit high vigor.</td></tr>
<tr><td colspan="4">Rationale: Generally, herbaceous plants in the lower streambank are full-size in stature; however, herbaceous swards are discontinuous and small and do not form widespread, continuous ribbons along the greenline as expected. The mature age class of woody trees and shrubs on terraces and floodplains appears to be vigorous, but woody seedlings and saplings and woody plants less than 5 feet in height (i.e., those with most of their leaders available to livestock and wildlife browse) have an altered growth pattern (e.g., hedged appearance with thick stems and short height for age) that suggests chronic browsing pressure (see photos 7a, 7b, and 3). In general, item 10 is a mixed bag depending on which age class of woody plants is inspected. The mature age class seems to be fine (potential for a yes response in this age class only), but younger ones are being chronically browsed and hedged (justification for a no response). The ID team examined the browsed leaders and determined that woody browse probably resulted from a mix of both livestock and wildlife use, judging from different styles of nip marks on tips of leaders.</td></tr>
<tr><td></td><td>✓</td><td></td><td>11) An adequate amount of stabilizing riparian vegetation is present to protect banks and dissipate energy during moderately high flows.</td></tr>
<tr><td colspan="4">Rationale: The streambank is sparsely vegetated with a lot of bare ground. Even though there is good diversity of desired riparian plants (see item 6), the cover of riparian perennial vegetation is low (estimated at 50% over the entire reach). Also, weakly rooted upland plants (e.g., Kentucky bluegrass, silver sagebrush) occur on the greenline along much of the reach (true of point bars, too; see item 14 and photo 6).</td></tr>
</table>

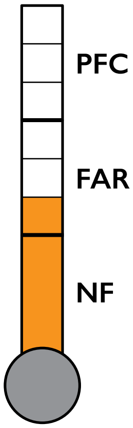
<table>
<tr><td></td><td></td><td>√</td><td>12) Plant communities are an adequate source of woody material for maintenance/recovery.</td></tr>
<tr><td colspan="4">Rationale: Mature cottonwood trees occur on the terrace, but few young cottonwood trees are available for recruitment. However, in this moderately low-gradient reach with very high sinuosity, energy can be dissipated by herbaceous plants on streambanks and meander bends. Therefore, woody material is not required for proper function. (See photos 2a-2c for an example of adequate herbaceous cover to dissipate energy in a reference reach.)</td></tr>
</table>

<table>
<tr><th>Yes</th><th>No</th><th>NA</th><th>GEOMORPHOLOGY</th></tr>
<tr><td>√</td><td></td><td>▨</td><td>13) Floodplain and channel characteristics (i.e., rocks, woody material, vegetation, floodplain size, overflow channels) are adequate to dissipate energy.</td></tr>
<tr><td colspan="4">Rationale: This is a weak yes. The channel has high sinuosity (~15; see photo 1), which dissipates a lot of energy. A broad, accessible floodplain permits dissipation of energy during annual peak-flow events. The floodplains are vegetated with riparian trees and shrubs and upland plants like silver sagebrush and mesic grasses, all of which add roughness to the floodplain. Energy dissipation appears to be adequate to prevent channel incision (downcutting). However, the lack of adequate streambank vegetation means streambanks are eroding in many, but not all, places (e.g., see photos 4, 5, and 6 for signs of bank erosion) and creating an overly wide channel in many places (see item 3). We believe that if riparian streambank vegetation is allowed to express, this item would become a strong yes. However, we are directing the comments and observations here to the condition of the floodplain and channel characteristics, not to streambank condition, which is the focus of item 11.</td></tr>
<tr><td></td><td>√</td><td></td><td>14) Point bars are revegetating with stabilizing riparian plants.</td></tr>
<tr><td colspan="4">Rationale: Weakly rooted upland plants occur along the greenline of many point bars and are inadequate to stabilize point bars and trap sediment. Consequently, many, though not all, point bars are actually eroding and losing sediment, rather than trapping sediment (see photo 6). Also refer to comment under item 11.</td></tr>
<tr><td></td><td>√</td><td></td><td>15) Streambanks are laterally stable.</td></tr>
<tr><td colspan="4">Rationale: Width/depth ratio appears to be high in many places (see photo 5), and streambanks are actively eroding in many spots due to the abundance of bare ground on the streambanks (see photos 4 and 6). The lateral instability is related to streambank erosion, not to channel avulsion.</td></tr>
<tr><td>√</td><td></td><td>▨</td><td>16) Stream system is vertically stable (not incising).</td></tr>
<tr><td colspan="4">Rationale: Although the channel appears to have incised back in the late 1870s and 1880s (based on dendrochronology of cottonwood trees, see photo 8; Gonzalez 2001a and 2001b), the postincision channel elevation appears to be stable. The recent change in channel dimension is from widening (see item 15), not incision.</td></tr>
<tr><td></td><td>√</td><td>▨</td><td>17) Stream is in balance with the water and sediment that is being supplied by the drainage basin (i.e., no excessive erosion or deposition).</td></tr>
<tr><td colspan="4">Rationale: Excess sediment is entering the creek and is evident from oversized fans and mid-channel bars that have formed at or near the confluences with tributaries. The ID team needs to study the uplands to get a better handle on the sources of this excess sediment, which might be from (1) the adjacent roadway, (2) recently burned hillslopes, or (3) heavily grazed upland sites, where we have observed surface rilling and flow patterns in quantities that exceed reference conditions (see reference sheets for Thin Loamy and Loamy ecological sites). Some tributary creeks may also have active headcut erosion. The channel is widening in places, so the excess sediment could be from channel erosion, too. We plan to drive the roadway to study culverts and ditches and to study aerial photography of drainages coming out of burned vs. unburned areas to identify sources of excess sediment. The lack of stabilizing streambank vegetation also means sediment is not being processed adequately; instead, sediment is being deposited during the waning stages of flow and then remobilized during subsequent high-flow events. We have ample evidence that sediment is being deposited on the floodplain.</td></tr>
</table>

Summary Determination

Functional rating (check one)

☐ Proper functioning condition
☑ Functional–at risk
☐ Nonfunctional



Trend (check one)

Monitored trend	**Apparent trend**
☐ Upward	☐ Upward
☐ Downward	☑ Downward
☐ Static	☐ Not apparent

Rationale for rating: Despite the rough appearance in parts of the reach, there are three important functions that are still operating in the reach: (1) the floodplain is still accessed by relatively frequent (annual or nearly annual) flow events, (2) the right type of hydric stabilizer plants are still found in the reach (though in low quantities), and (3) the shallow alluvial aquifer has not dropped and still provides seasonlong moisture to obligate wetland and facultative wetland plants on the streambanks, so the system is not completely without function. However, the streambanks do not have nearly enough vegetation cover to trap sediment and to dissipate energy to protect the streambanks from erosion. The desired herbaceous riparian plant species are found in the reach, but they occur in patchy, discontinuous communities and do not have widespread distribution along the streambanks. Consequently, the raw materials for recovery are present, and management should be changed to allow these communities the opportunity to expand, gain vigor, and recruit a younger cohort.

It is also possible that we are witnessing a geomorphic response (i.e., channel widening and high sediment flux) in response to higher runoff volumes from parts of the drainage basin that burned 6 years ago in the Specimen Fire in the fall of 2008.

Rationale for trend: The change in channel dimensions toward a wider channel may be the start of other changes (such as loss of floodplain connectivity) that may have more dramatic impacts on riparian function.

Are there factors present preventing the achievement of PFC or affecting progress towards desired condition that are outside the control of the manager?

☐ Yes ☑ No

If yes, what are those factors? Check all that apply.

☐ Flow regulations	☐ Road encroachment
☐ Mining activities	☐ Oil field water discharge
☐ Upstream channel conditions	☐ Augmented flows
☐ Channelization	☐ Other (specify:)

Explain factors preventing achievement of PFC: The ID team needs to study upland conditions to get a better idea of the causes of recent channel widening and the source of excess sediment. Some on the ID team believe we are observing a geomorphic response to the wildfire that occurred 6 years ago in the fall of 2008. The Specimen Fire removed a lot of juniper on north-facing slopes in the drainage basin. We need to use aerial photography and field inspections to compare tributaries from severely burned to lightly burned or unburned parts of the drainage basin. The loss of ground cover could explain an increase in sediment production and an increase in peak flood volumes (enough to simultaneously widen the channel and still access and inundate the floodplain). We also want to examine the adjacent roadway and investigate culverts and drainage ditches to see if excess runoff and sediment are being generated by the roadway. The upland areas with chronic overgrazing are pretty well known. Annual use-pattern mapping or utilization studies should be continued to see if local areas of overuse are being better managed. Changes in salt distribution and more frequent riding to control livestock distribution may help. The sparseness of hydric riparian vegetation on the streambank remains problematic. A test exclosure might be useful in determining if riparian use levels and hoof alterations are causing and maintaining degraded conditions. Could riparian vegetation cover increase simply by reducing streambank alteration and streambank herbivory?

Our monitoring plans include:

- Establishment of a DMA for multiple indicator monitoring to see if changes in management or time since the Specimen Fire lead to improved riparian function, especially in vegetation cover and greenline-to-greenline width; also need to see if management changes can decrease woody use and increase willow and cottonwood recruitment.
- Investigation of uplands (by aerial photography and field inspections) to determine the potential source(s) of excess sediment.
- Coordination with rangeland specialists to complete use-pattern mapping and rangeland condition monitoring on targeted grama flats.

(Revised 2014)

Lotic PFC Riparian Plant List Form

Riparian area/stream name: Specimen Creek Reach ID: R1-BSNF-SPCR-08 Date: 07/01/2014

Region (USACE or other): Great Plains

√	Plant Symbol	Common Name	Scientific Name	AB	GS	WIC	SC	IN
Trees/Shrubs								
	ACNE2	Boxelder	*Acer negundo*			FACW*	H	
√	ARCA13	Silver sagebrush	*Artemisia cana*	4	T, F	FAC*	L	
	BEOC2	Water birch	*Betula occidentalis*			FACW	H	
	CEOC	Common hackberry	*Celtis occidentalis*			FACU	M	
	COSE16	Redosier dogwood	*Cornus sericea*			FACW	H	
	ELAN	Russian olive	*Elaeagnus angustifolia*			FACW*	M	X
√	PODEM	Plains cottonwood	*Populus deltoides*	3	T, F	FACW*	H	
	POTR5	Quaking aspen	*Populus tremuloides*			FAC	H	
√	PRVI	Chokecherry	*Prunus virginiana*	2	T, F	FACU	H	
√	RHTR	Skunkbush sumac	*Rhus trilobata*	2	T, F	FACU	M	
	RIAU	Golden currant	*Ribes aureum*			FACU	M	
√	ROWO	Woods' rose	*Rosa woodsii*	2	F	FACU	M	
	SAAM2	Peachleaf willow	*Salix amygdaloides*			FACW	H	
√	SAEX	Coyote willow	*Salix exigua*	2	B, F, PB	FACW	M	
	SHAR	Silver buffaloberry	*Shepherdia argentea*			FACU*	M	
√	SYOC	Western snowberry	*Symphoricarpos occidentalis*	2	T, F	FACU*	M	
	TACH2	Five-stamen tamarisk	*Tamarix chinensis*			FACW	H	X
Graminoids/Grasses								
√	CAPE42	Woolly sedge	*Carex pellita*	2	B	OBL	H	
√	CANE2	Nebraska sedge	*Carex nebrascensis*	3	B	OBL	H	
	CALA11	Woollyfruit sedge	*Carex lasiocarpa*			OBL	M	
	CAMI7	Smallwing sedge	*Carex microptera*			FAC	M	
	ELAC	Needle spikerush	*Eleocharis acicularis*			OBL	M	
√	ELPA3	Common spikerush	*Eleocharis palustris*	1	B, C	OBL	M	
√	JUBA	Baltic rush	*Juncus balticus*	3	B, F	FACW	H	
	JUEN	Swordleaf rush	*Juncus ensifolius*			FACW	M	
	JUTO	Torrey's rush	*Juncus torreyi*			FACW	H	
	SCAC3	Hardstem bulrush	*Schoenoplectus acutus*			OBL	H	
√	SCPU10	Common threesquare bulrush	*Schoenoplectus pungens*	3	B, C	OBL	H	
√	SCMI2	Panicled bulrush	*Scirpus microcarpus*	2	C, B	OBL	H	
	AGST2	Creeping bentgrass	*Agrostis stolonifera*			FACW	L	
	ALAR	Creeping meadow foxtail	*Alopecurus arundinaceus*			FACW	L	
	BESY	American sloughgrass	*Beckmannia syzigachne*			OBL	MM	
	CACA4	Bluejoint reedgrass	*Calamagrostis canadensis*			FACW	H	
	DECE	Tufted hairgrass	*Deschampsia cespitosa*			FACW	M	
√	DISP	Inland saltgrass	*Distichlis spicata*	4	B, F	FACW	M	
√	ELCA4	Canada wildrye	*Elymus canadensis*	3	F	FAC*	M	

√	Plant Symbol	Common Name	Scientific Name	AB	GS	WIC	SC	IN
	ELTR7	Slender wheatgrass	*Elymus trachycaulus*			FACU	L	
√	GLGR	American mannagrass	*Glyceria grandis*	1	B	OBL	H	
	GLST	Fowl mannagrass	*Glyceria striata*			OBL	M	
√	HOJU	Foxtail barley	*Hordeum jubatum*	2	C, B	FACW	L	
√	MUAS	Alkali muhly	*Muhlenbergia asperifolia*	2	F, B	FACW	L	
	MUGL3	Spiked muhly	*Muhlenbergia glomerata*			FACW	M	
√	PASM	Western wheatgrass	*Pascopyrum smithii*	4	T, F	FACU	M	
	PHAR3	Reed canarygrass	*Phalaris arundinacea*			FACW	M	
	POAR3	Plains bluegrass	*Poa arida*			FAC	L	
√	POPR	Kentucky bluegrass	*Poa pratensis*	4	F, T, S	FACU	L	
√	PUNU2	Nuttall's alkaligrass	*Puccinellia nuttalliana*	2	B	OBL	M	
√	SPGR	Alkali cordgrass	*Spartina gracilis*	2	F, B	FACW	H	
√	SPPE	Prairie cordgrass	*Spartina pectinata*	2	B	OBL*	H	
Forbs								
√	CIAR4	Canada thistle	*Cirsium arvense*	2	F	FACU	L	X
	COMA2	Poison hemlock	*Conium maculatum*			FACW	L	
	EQAR	Field horsetail	*Equisetum arvense*			FAC	M	
√	EQHY	Scouringrush horsetail	*Equisetum hyemale*	3	F	FACW	M	
√	EQLA	Smooth horsetail	*Equisetum laevigatum*	3	F	FACW*	L	
√	EUES	Leafy spurge	*Euphorbia esula*	2	T, F, S	FACU	L	X
√	GLLE3	American licorice	*Glycyrrhiza lepidota*	3	F	FAC*	M	
√	HEMA2	Maximilian sunflower	*Helianthus maximiliani*	1	F	FACU	H	
	LYSA2	Purple loosestrife	*Lythrum salicaria*			OBL	M	X
√	MEAR4	Wild mint	*Mentha arvensis*	2	F, B	FACW	L	
	NAOF	Watercress	*Nasturtium officinale*			OBL	L	
	TYAN	Narrowleaf cattail	*Typha angustifolia*			OBL	H	
	TYLA	Common cattail	*Typha latifolia*			OBL	H	
√	XAST	Rough cocklebur	*Xanthium strumarium*	2	C, B, F	FAC	L	

Notes: Leafy spurge and Canada thistle locations documented with GPS for later treatment--
see Vegetation-Noxious Weed GPS folder for shape files.
* WIC modified from National Wetland Plant List based on information from Hansen et al. (1995) and local
understanding of plant distribution.

Photo 1. Overview of Specimen Creek, reach 8. Note high sinuosity, wide alluvial valley bottom, and badlands hillslopes that generate high sediment supply. (Image obtained from Esri World Image Service. World_Imagery - Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, AeroGRID, IGN, IGP, and the GIS User Community).

Photo 2a. A reference site illustrates a typical wide valley bottom and the effects of a shallow alluvial aquifer, which provides seasonlong moisture to support obligate wetland and facultative wetland species even though the channel is dry during much of the growing season.

Photo 2b. A reference site shows a comparatively narrow, deep channel. A common threesquare bulrush (*Schoeneplectus pungens*) community dominates the right bank and floodplain.

Photo 2c. Another reference site illustrates the opportunistic nature of riparian shrubs and trees to establish on recent point-bar and floodplain deposits. Coyote willow (*Salix exigua*) has colonized the point bar on the left bank and is effective at trapping sediment (light-colored deposits) to create and maintain Rosgen C stream-type channels.

Photo 3. Overbank flow on the floodplain is evident from (1) plant material that is trapped by woody plants or lodged on the upstream side of tree trunks, (2) fine herbaceous plants that are bent in the direction of flow, and (3) thin increments of silt and clay (light-colored sediment in photograph) deposited on the floodplain.

Photo 4. In this reach, low-head beaver dams are constructed with small-dimensioned sticks and mud. These dams are easily breached or removed by high flows.

Photo 5. Recent channel widening is evident from a combination of sparsely vegetated streambanks, slump blocks, cutbanks along straight channel segments, and a high width/depth ratio along much of the reach.

Photo 6. Many (though not all) point bars in this reach are not being vegetated with stabilizing riparian plants. Instead, the greenline is back on the floodplain and coincides with upland vegetation such as silver sagebrush (*Artemisia cana*) and mesic grasses on the far bank. A lot of sediment is draped on the point bar, indicative of a lot of sediment transport, but many point bars, including this example, are being actively eroded due to the lack of stabilizing vegetation and the apparent inability to effectively control stream energy during high-flow events.

Photo 7a. Chronic browsing pressure has altered the growth form of this plains cottonwood (*Populus deltoides*) from a single-stemmed to a multistemmed plant. Also, the plant's height is far less than expected for a tree that is several years old.

Photo 7b. A community of coyote willow (*Salix exigua*) has been chronically browsed. Consequently, the height of the plants is far less than expected for the plant's age, and the stems are far less dense than expected for a rhizomatous plant (compare to photo 2c).

Photo 8. Mature cottonwoods, more than 120 years old and positioned on a terrace 6-8 meters above the floodplain, indicate that the channel incised during the late 1800s. Younger cottonwoods have formed subsequent to channel incision on the modern point bars and floodplain and indicate relative bed-elevation stability over the past 100-120 years. Dendrochronology of cottonwood trees and incision history provided by Gonzalez (2001a, 2001b).

Glossary

Active channel – The nonvegetated part of the channel that typically coincides with the scour line and/or greenline on the streambank.

Aggradation – The geologic process by which a stream bottom or floodplain is raised in elevation by the deposition of material.

Alluvial – Deposited by running water.

Altered potential – The best possible ecological status and channel form that can be attained under permanent human alterations.

Anastomosing channels – Multiple channels with relatively permanent, stable, vegetated islands. Banks are cohesive and sediment load is primarily suspended load.

Bankfull or bankfull stage – The elevation of the bank where flooding begins. Bankfull is the streamflow level 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 formation of the morphological characteristics of the stream channel (Wolman and Miller 1960).

Bankfull channel – The channel size and shape that hold the bankfull discharge.

Bankfull discharge – The maximum discharge that a particular stream channel is capable of carrying without flooding.

Channel avulsion – Rapid abandonment of a river channel and the formation of a new river channel.

Community type – A repeating classified and recognizable assemblage or grouping of plant species. They often occur as patches, stringers, or islands and are distinguished by floristic similarities in both their overstory and understory layers.

Degradation – A geologic process that lowers the stream channel due to erosion. Also referred to as downcutting.

Ecological site (riparian) – A conceptual division of the landscape, defined as a distinctive kind of land based on recurring soil, landform, geological, and climate characteristics that differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its ability to respond similarly to management actions and natural disturbances. Ecological site is synonymous with range site.

Ecotone – A transition area of vegetation between two communities that has characteristics of both kinds of neighboring vegetation as well as characteristics of its own. Ecotones vary in width depending on site and climatic factors.

Entrenchment – The relationship of the stream channel to its valley and landform features. It is qualitatively defined as the vertical containment of a channel and the degree to which it is incised in the valley floor.

Ephemeral system – A stream system that flows only in direct response to precipitation. It receives no water from springs and no long-continued supply from melting snow or other surface sources. Its stream channel is at all times above the water table. The term ephemeral may be arbitrarily restricted to streams or stretches of streams that do not flow continuously during periods of as much as 1 month (Meinzer 1923). An ephemeral stream does not exhibit the typical biological, hydrological, and in some cases, physical characteristics associated with the continuous or intermittent availability of water (Nadeau 2011). The PFC assessment protocol is not designed for use on ephemeral streams or ephemeral reaches.

Floodplain – A relatively flat landform adjacent to a stream that is composed of primarily unconsolidated depositional material derived from the stream and that is subject to periodic flooding. The floodplain is inundated at least once or twice (on average) every 3 years.

Fluvial – Shaped by the movement of water, particularly channelized flow.

Gaining stream – A stream reach that gains water from the inflow of ground water through the streambed. In some environments, streamflow gain can persist; that is, a stream might always gain water from ground water. However, in other environments, flow direction can vary a great deal along a stream; some reaches receive ground water, and other reaches lose water to ground water. Furthermore, flow direction can change in very short timeframes as a result of individual storms causing focused recharge near the streambank, temporary flood peaks moving down the channel, or transpiration of ground water by streamside vegetation (Winter et al. 1998).

Geomorphology – The study of landforms and the processes that shape them.

Greenline – The first perennial vegetation that forms a lineal grouping of community types at or near the water's edge along a stream channel. Most often it occurs at or slightly below the bankfull stage (Burton et al. 2011; Winward 2000).

Hydraulic control – A feature of landform (bedform and bed material), vegetation, or organic debris that controls the relationship between stage (water depth) and flow rate (discharge) of a stream.

Hydraulic radius – The ratio of the cross-sectional area to the wetted perimeter (the part of the channel bed that is in contact with water in a cross-sectional view.)

Hydric – Characterized by, relating to, or requiring an abundance of moisture.

Hydroperiod – The period of time during which soils, water bodies, and sites are wet.

Hyporheic zone – A unique hydrochemical and biological region beneath and lateral to a streambed, where there is mixing of ground water and surface water.

Incised channel – A stream channel that has cut into the bed of the valley due to erosive lowering of the streambed, which keeps the stream from accessing its floodplain in relatively frequent events.

Intermittent system – A stream system that flows only at certain times when it receives water from springs or gradual and long, continued snowmelt. The intermittent character of streams of this type is generally due to fluctuations of the water table whereby part of the time the streambed is below the water table and part of the time it is above the water table. The term intermittent may be arbitrarily restricted to streams or stretches of streams that flow continuously during periods of at least 1 month (Meizner 1923). An intermittent stream may lack the biological and hydrological characteristics commonly associated with the continuous conveyance of water (Nadeau 2011). The channel may or may not be well defined.

Interrupted reach – A stream that contains: (1) perennial stretches with intervening intermittent or ephemeral stretches, or (2) intermittent stretches with intervening ephemeral stretches (Meizner 1923).

Lentic – A riparian system characterized by still water (such as lakes, ponds, or swamps).

Losing stream – A stream reach that loses water to ground water by outflow through the streambed. Losing streams can be connected to the ground-water system by a continuous saturated zone or can be disconnected from the ground-water system by an unsaturated zone. In some environments, streamflow loss can persist; that is, a stream might always lose water to ground water. However, in other environments, flow direction can vary a great deal along a stream; some reaches receive ground water, and other reaches lose water to ground water. Furthermore, flow direction can change in very short timeframes as a result of individual storms causing focused recharge near the streambank, temporary flood peaks moving down the channel, or transpiration of ground water by streamside vegetation (Winter et al. 1998).

Lotic – A riparian system characterized by actively moving water.

Mean-annual flood – The average of annual peak flows for a period of record.

Perennial system – A stream system that flows continuously in all or most years. It is generally fed in part by springs, and the streambed is often located below the water table for most of the year. Ground water supplies the baseflow for perennial streams during dry periods, but flow is also supplemented by stormwater runoff and snowmelt (Meizner 1923; Nadeau 2011). A perennial stream exhibits the typical biological, hydrological, and physical characteristics commonly associated with the continuous conveyance of water (Nadeau 2011).

Potential – The highest ecological status a riparian area (stream reach) can attain in the present climate.

Redoximorphic features – Soil features formed by the process of reduction, translocation, or oxidation of iron and manganese oxides; formerly called mottles and low-chroma colors (USDA-NRCS 2010.)

Sinuosity – The ratio of channel length to valley length.

State-and-transition model – A method to organize and communicate complex information about the relationships among vegetation, soil, animals, hydrology, disturbances (fire, lack of fire, grazing and browsing, drought, unusually wet periods, insects, and disease), and management actions on an ecological site (USDI-BLM et al. 2013.)

Stream energy or stream power – A measure of a stream's ability to erode and transport sediment that is equal to the product of shear stress and velocity.

Thalweg – The line that connects the lowest or deepest (or maximum water depth) points along the streambed.

Watershed – A region or area that is bounded peripherally by a drainage divide and that drains ultimately to a particular watercourse or body of water; a drainage basin for a stream or a catchment.

Woody material – Pieces of wood in a stream that affect channel morphology by splitting flows, dissipating stream energy, and capturing and storing sediment/bedload. Beyond a minimum threshold, size varies with stream size but generally can be described as large enough to have a low probability of being moved by the stream (Bilby and Ward 1987). Pieces with a length of one-half the channel width or larger are generally considered stable (Bisson et al. 1987).

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