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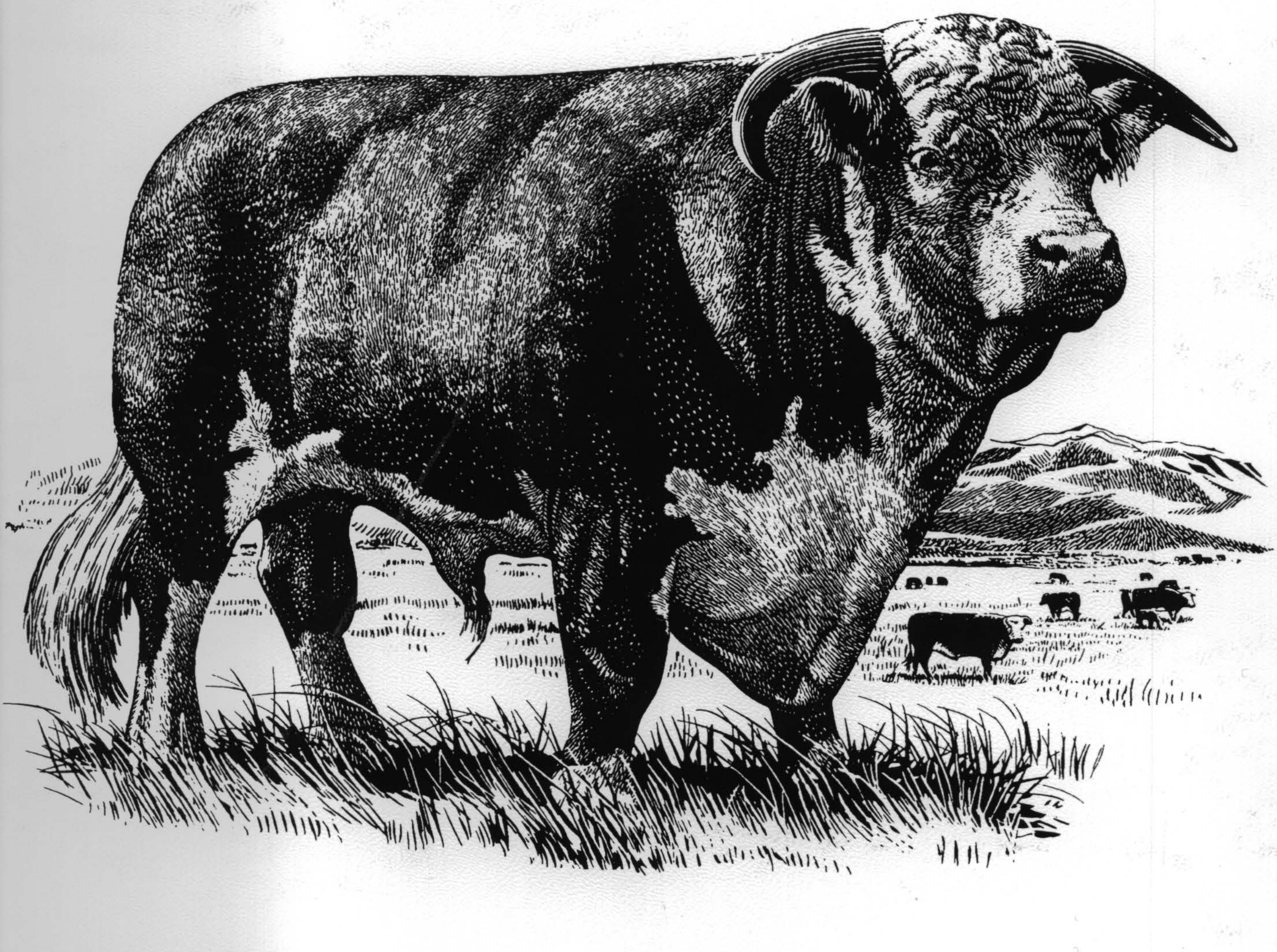
Monitoring Protocols to Evaluate Water Quality Effects of Grazing Management on Western Rangeland Streams



MONITORING PROTOCOLS TO EVALUATE WATER QUALITY EFFECTS OF GRAZING MANAGEMENT ON WESTERN RANGELAND STREAMS

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I. INTRODUCTION

PURPOSE

This document describes a monitoring system to assess grazing impacts on water quality in streams of the western United States. The protocols were developed to assess water quality improvement resulting from stream restoration projects funded under the Clean Water Act Amendments of 1987 and the Coastal Zone Management Act as amended in 1990. A companion document addressing upland monitoring methods will also be published (Bedell and Buckhouse, 1993. *Monitoring primer for rangeland watershed).*

The monitoring methods were selected for application by natural resource professionals typically involved in these projects. This includes resource professionals with backgrounds in soils, range, hydrology, fisheries biology, and water quality. Projects are often implemented by state water quality agencies, Soil Conservation Districts, USDA Soil Conservation Service, USDA Forest Service, USDI Bureau of Land Management, tribes, and other state and federal entities.

A goal for this project is to describe methods that are easy to use and cost-effective. This is achieved by using methods that reduce sample frequency, minimize the need for specialized equipment, and reduce costly laboratory analyses. The document focuses primarily on attributes of the stream channel, stream bank, and streamside vegetation of wadable streams which are impacted by grazing and are important to support aquatic life. These characteristics are sampled during the low flow conditions in the summer when streams can be waded. The methods require relatively inexpensive equipment compared to standard water chemistry analysis techniques. Implementation of these methods requires building and training an interdisciplinary monitoring team.

GRAZING AS A NONPOINT SOURCE ACTIVITY

Livestock grazing is an important industry on state, private, and federal rangelands in the western United States. States which comprise much of the western rangelands include Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. The USDI Bureau of Land Management (BLM) authorized use of 13.5 million Animal Unit Months (AUM) on approximately 167 million acres in 1991 (USDI BLM, 1992) and the USDA Forest Service authorized use of 7.6 million AUMs on 49 million acres in 1992 (USDA FS, 1993). Two hundred nine million acres of private land are classified as rangeland in the western states (USDA SCS, 1989).

In the West, livestock are attracted to riparian areas, those areas adjacent to streams and rivers, because of succulent forage, accessibility, shade, a reliable water supply, and a microclimate more favorable than that of the surrounding terrain (Skovlin, 1984). Riparian areas constitute important sources of livestock forage; one acre of meadow has the potential grazing capacity equal to 10 to 15 acres of surrounding forested range. In the Pacific Northwest, riparian meadows often cover only 1 to 2 percent of the summer range area, but provide about 20 percent of the summer forage (Clary and Webster, 1990). In some areas, 80 percent of the forage consumed may come from these meadows (Kauffman and Krueger, 1984).

Livestock impacts, through excessive grazing and trampling, affect stream habitats by reducing or eliminating riparian vegetation, changing streambank and channel morphology, and increasing stream sediment transport (Clary and Webster, 1990).

Average forage conditions of rangelands, primarily uplands, have been estimated for some rangelands. These percentages are shown in Table 1.1. Riparian condition is not consistently reported by management agencies; however streamside areas typically receive 20 to 30 percent greater use than adjacent upland ranges (Platts, 1991). The accelerated use of streamside areas combined with the percent of rangelands reported in fair and poor forage conditions provides some indication of the potential widespread effects of grazing.

Table 1.1. Average forage condition of rangelands, by land ownership

Nonfederal lands:	2% excellent, 29% good, 47% fair, 13% poor, and 9% other (SCS, 1989).
BLM lands:	5% excellent, 31% good, 36% fair, 15% poor, and 13% unclassified (BLM, 1992).

The dimensions of nonpoint source impacts from grazing is not well documented. State nonpoint source reports provided to EPA usually combine stream miles affected by grazing in a general category with agriculture. This makes inventory of stream miles affected solely by rangeland difficult to assess. In the 1989 report to Congress, states listed 2,000 waterbody segments that were impaired by rangeland activities (EPA, 1992). Most range-related problems were reported from Idaho, Oregon, Wyoming, and Arizona.

THE CLEAN WATER ACT AND COASTAL ZONE MANAGEMENT ACT

The goal of the Clean Water Act (CWA) is to "**restore and maintain the chemical, physical, and biological integrity of the Nation's waters**." In 1987, Section 319 was added to the CWA to provide additional emphasis on preventing and correcting nonpoint source pollution problems. Section 319 places the primary responsibility for controlling nonpoint source pollution on the states. As a result of Section 319 states have completed an assessment of waters impacted by nonpoint source activities and developed nonpoint source management programs. Annual grants are awarded to states by EPA to implement nonpoint source controls and develop watershed restoration projects to meet the goal of the CWA.

Historically, water quality programs have focused on methods to evaluate the chemical integrity of water, in relation to some standard which assures support of beneficial uses. Criteria are typically based on toxicity tests made in the laboratory. This approach has been limited in its usefulness. Karr (1991) noted that, "Although perception of biological degradation stimulated current state and federal legislation on the quality of water resources, that biological focus was lost in the search for easily measured physical and chemical surrogates." Overgrazing impacts fisheries habitat which precludes achievement of the Clean Water Act objectives to maintain the biological integrity of the Nation's waters.

EPA has increased emphasis on biocriteria and biomonitoring. States are expected to adopt narrative biological criteria into state water quality standards by 1993. Biological criteria incorporate the concept of biological integrity which is defined as:

> " the condition of the aquatic community inhabiting the unimpaired waterbodies of a specific habitat as measured by community structure and function" (EPA, 1990).

EPA recommends that states accomplish development of biological criteria through resource inventory, identification of reference areas with desirable conditions, and comparison of waterbodies to these reference areas (Gibson, 1991). The monitoring system described in this report incorporates these ideas by using reference areas to define project and monitoring objectives.

The 1990 amendments to the Coastal Zone Management Act require coastal states to develop programs to protect their coastal watersheds from non-point source pollution. In contrast to the Clean Water Act, the Coastal Zone Management Act requires state programs which contain enforceable policies and mechanisms to implement nonpoint source pollution management measures. EPA has issued the document, Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters, which includes guidelines with which State programs must conform in order to receive implementation funding from EPA (EPA, 1993).

ORGANIZATION AND USE OF THE GUIDELINES

Section II of this report describes the impacts of grazing on the stream ecosystem. A critical step in developing a monitoring program is to establish the relationship between the nonpoint source activity, livestock grazing, and the effect on beneficial uses. Section II summarizes information on the potential effects of grazing on the stream/riparian ecosystem and its relationship to beneficial uses. Cold water biota, specifically salmonids, are often the most sensitive indicator of impacts from western rangelands and are emphasized in this review. An understanding of potential grazing effects provides a basis for selecting monitoring parameters.

Section III describes the recommended steps for developing a monitoring plan (summarized in Table 1.2). Initially, resource concerns are identified. Stream reach stratification and classification are conducted. Field reconnaissance then provides an assessment of existing conditions and additional information to refine initial assumptions regarding the effect of grazing on water quality.

Table 1.2. Steps in developing the monitoring program

Identify issues and concerns.
Stratify and classify stream reaches.
Conduct reconnaissance: assess existing conditions and refine water quality issues.
Establish specific goals and objectives.
Select parameters and monitoring design.
Select representative monitoring and reference sites.
Conduct first year of pilot project monitoring.
Reassess assumptions and objectives and modify the monitoring plan.

Reference area monitoring is recommended as the preferred method for defining the benchmark condition and site-specific objectives. The monitoring program is reassessed and modified based on first year or pilot project monitoring.

Section IV describes the process for stream stratification, reconnaissance, and classification. This section describes a process to stratify stream reaches using geomorphology (stream type), dominant soils, and riparian vegetation communities. The stratification provides a template for selecting representative monitoring sites and reference areas. The stratification and classification procedure is based on methods described in the Integrated Riparian Evaluation Guide (USFS, 1992) and modified by Idaho Department of Health and Welfare, Division of Environmental Quality, for their Agricultural Nonpoint Source Program (Cowley, 1992). The field reconnaissance also provides an evaluation of the existing stream habitat condition. This procedure requires an interdisciplinary team with skills in riparian plant identification, fisheries habitat assessment, stream type classification, and soils classification.

Section V contains an evaluation of monitoring methods. Monitoring methods commonly used to assess the effects of grazing on water quality were evaluated for their use in a monitoring program. The methods were evaluated on the basis of sample frequency, time needed for sample collection, equipment required, cost of laboratory analysis, expertise required, technique precision and accuracy, natural variability, preferred flow/site condition, and ease of use. Based on this evaluation, a set of methods which are relatively easy to use and cost-effective is recommended. The advantages and disadvantages of using these methods are also described in this section.

Section VI contains a description of the recommended monitoring protocols or methods. Each description includes an overview describing the rationale for application and use of the method. Data collection and analysis procedures are described in detail. Forms for recording data and a list of equipment needed for each protocol are provided. Individual monitoring protocols are written to stand alone. However, it is important to use the process described in Section IV, or one similar, to stratify and classify stream reaches prior to selecting monitoring sites.

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II. IMPACTS OF GRAZING ON WATER QUALITY AND BENEFICIAL USES

Livestock grazing has the potential to cause detrimental effects on the beneficial uses of water. Nonpoint source effects fall into three categories: 1) a change in the chemical, physical, and bacteriological characteristics of water; 2) modification of habitat by changes to the stream channel and vegetation; and 3) changes to stream flow patterns.

Monitoring should focus on those factors which limit the beneficial uses in the watershed. A successful monitoring program identifies site-specific impacts and targets those parameters that provide a linkage between the effect of grazing and the resulting impact on the beneficial use. This section briefly reviews the impacts of grazing on the watershed, the riparian zone, and the beneficial uses of water. The maintenance of cold water biota, especially salmonid fisheries, is an important objective of resource managers. Salmonid habitat requirements and the impacts of grazing on salmonid habitat are specifically addressed.

Livestock grazing affects the watershed and especially the stream corridor. Grazing has potentially detrimental effects on the stream banks, water column, aquatic life, stream channel, and riparian vegetation. Table 2.1 summarizes the potential effects of livestock grazing on each of these resources.

Table 2.1. Potential effects of grazing on aquatic and riparian resources (Platts, 1989)

<u>**Water Column**</u>

1. Withdrawal of stream flow to irrigate grazing lands.
2 Drainage of wet meadows or lowering of the groundwater table to facilitate grazing access.
3. Pollutants (e.g., sediments) in return water from grazed pasture lands.
4. Change in magnitude and timing of organic and inorganic energy inputs to the stream (i.e., solar radiation, debris, nutrients).
5. Increase in fecal contamination.
6. Change in water column channel morphology, such as an increase in stream width and decrease in stream depth, including reduction of streamshore water depth.
7. Change in timing and magnitude of stream flow events from change in watershed vegetative cover.
8. Increase in stream temperature.

<u>**Stream Banks**</u>

1. Shearing or sloughing of stream bank soils by hoof or head action.

2. Water, ice, and wind erosion of exposed stream bank and channel soils because of loss of vegetation cover.
3. Elimination or loss of stream bank vegetation.
4. Reduction of the quality or and quantity of stream bank undercuts.
5. Increasing stream bank angle which increases water width and decreases water depth.

Stream Channel

1. Change in channel morphology.
2. Altered stream sediment transport processes.

Riparian Vegetation

1. Change in plant species composition (e.g., brush to grass to forbs).
2. Reduction of floodplain and stream bank vegetation, including vegetation hanging over or entering the water column.
3. Decrease in plant vigor.
4. Changes in timing and amount of organic energy leaving the riparian zone.
5. Elimination of riparian plant communities (i.e., lowering of the water table allowing xeric plants to replace riparian plants).

EFFECTS OF GRAZING ON THE WATER COLUMN

Nutrients

Nutrients in animal wastes may stimulate algae and aquatic plant growth. Moderate aquatic plant growth provides a food base for the aquatic community, living space for invertebrates, and hiding cover for fish. At excessive levels, aquatic plant growth may contribute to low dissolved oxygen levels during night-time respiration which may be detrimental to beneficial uses. The concentration of disssolved oxygen is also affected by temperature. At higher temperatures, the concentration of dissolved oxygen decreases.

Nutrients can be measured in many forms, but a useful set of parameters includes nitrate-nitrogen, total phosphorus, and soluble phosphorus. Ammonia may be considered useful if animal wastes are particularly concentrated.

Nutrient impacts vary considerably in study results. Specific site conditions such as precipitation, runoff, vegetation cover, grazing density, proximity to the stream, and period of use affect the results.

Nutrient effects are usually expressed in combination with other changes to the system. Aquatic plant growth is favored in shallow, wide channels where fine sediments provide a rooting medium and a reduced canopy allows additional solar radiation. Downstream impacts from nutrients are important when the receiving water is a lake or reservoir.

The decision to evaluate nutrient concentrations depends on the sensitivity of the beneficial uses of water. Nutrient monitoring should also be a primary consideration for streams that empty into lakes or impoundments.

Nutrients stimulate algal and aquatic plant growth at very low concentrations. The Environmental Protection Agency (EPA) recommends total phosphates not to exceed 50 ug/l (micrograms per liter) for a stream at the point where it enters a lake or reservoir, and a maximum of 100 ug/l for other streams (EPA, 1989). It is generally recommended that concentrations of nitrate not exceed 300 ug/l.

Nutrient enrichment is a function primarily of waste concentration and opportunity for its runoff into the stream. Schepers and Francis (1982) found increases in nutrients in a cow-calf pasture in Nebraska; nitrates increased 45 percent and total phosphorus increased 37 percent. Nutrient levels were correlated primarily with grazing density (Schepers et al., 1982).

The risk of nutrient enrichment is low in arid rangelands where animal wastes are distributed and runoff is comparatively light. Studies by the Agricultural Research Service and Bureau of Land Management found little evidence of nutrient enrichment from unconfined livestock grazing in Reynolds Creek, an arid watershed in southern Idaho (ARS, 1983).

Nutrient loss is minimal where the streamside pasture remains in good condition. Vegetation buffers the stream from direct waste input and assimilates the nutrients into plant tissue. Gary et al. (1983) evaluated the effects on a small stream in central Colorado of spring cattle grazing on pastures. Manure recovered within 3 meter strips on each side of the stream accounted for 4 percent to 6 percent of the total expected manure production. Nitrate nitrogen did not increase significantly and ammonia increased significantly only once. Although the authors document direct stream deposition, nutrient increase was limited because the pastures were in good condition and grazed only moderately in the spring.

Nutrient concentrations were low in a continuously grazed unimproved pasture in a humid site in east-central Ohio (Owens et al., 1989). An earlier study on the same site, using only summer grazing, showed that nutrients did not increase significantly (Owens et al., 1983).

Dixon et al. (1983) examined chemical and bacteriological loss from a cow-calf wintering area in southern Idaho; the area was irrigated and return flows entered the stream. The concentration of nitrogen and phosphorus in runoff was a fraction of that observed from cattle feedlots. The authors concluded that the loss of nutrients was small.

Bacteria

Bacteria from the intestinal tract of warm-blooded animals are indicators of fecal contamination and the presence of microbial pathogens. Most state water quality standards use fecal coliform bacteria (FC) as the indicator for determining suitability of the water for recreational use and as a domestic water supply.

Studies have shown that livestock grazing increases fecal coliform counts over background (Doran and Linn, 1979; Gary et al., 1983; Tiedeman, 1987). Bacterial counts increase after cattle are turned in and may remain high after cattle are removed (Stephenson and Street, 1978; Jawson et al., 1982).

The primary mechanism for bacterial contamination appears to be direct deposition of fecal material in the stream or transport of fecal material to the stream via overland flow (Miner, 1992). In arid rangelands, bacterial contamination may be minimal. Coliform bacteria stayed within a few feet of the manure on a dry Utah rangeland (Buckhouse and Gifford, 1976). On rangeland sites in Reynolds Creek in southwestern Idaho, geometric mean values did not exceed 50/100 ml. (ARS, 1983,).

Once bacteria reaches a stream, bottom sediment may act as a reservoir. When manure was deliberately added to the stream, most of the organisms, 90 percent or more, settled to the stream bottom (Sherer et al., 1988). Resuspension of sediments may increase bacterial numbers (Stephenson and Rychert, 1982). Sherer et al. (1988) reported that deliberate stream disturbance, by raking the stream bottom, resuspended sediment and increased bacterial counts. Resuspension also occurs when stream flow increases or when animals walk through streams.

Some additional considerations for monitoring design are provided by Bohn and Buckhouse (1985). Coliform populations exhibit daily and seasonal cycles which may influence results. As a result, individual samples represent only the status at the time of sampling. Coliforms may survive in feces for long periods, up to a year, and coliform concentrations increase with storm and runoff events. Wildlife also contribute to bacterial numbers which may influence results. Finally, coliforms may not be satisfactory indicators since they may die off while pathogens remain viable.

Baxter-Potter and Gilliland (1988) made the following conclusions from a literature review of bacterial pollution from agricultural lands. Like other researchers they found the proximity of fecal contamination to the watercourse is significant. If the bacteria can not be transported by overland flow, their contribution to pollution will be minor. They found increased discharge during storms may increase bacterial densities. Other factors, including temperature, wildlife activity, fecal deposit age, and channel and bank storage, affect bacterial densities in runoff.

GRAZING IMPACTS ON THE WATERSHED

Livestock grazing affects watershed properties by alteration of plant cover and by soil compaction from the physical action of animal hooves. Reductions in the vegetation cover may in turn increase the impact of raindrops, decrease soil organic matter and soil aggregates, increase surface crusts, and decrease water infiltration rates. These effects may cause increased runoff, reduced soil water content, and increased erosion (Blackburn, 1983).

The hydrologic impacts of grazing intensity are related primarily to infiltration and runoff. An extensive review of studies relating grazing intensity to infiltration rates (Gifford and Hawkins, 1978) showed that there is an influence of grazing on infiltration rates including light/moderate intensities; there is also a distinct impact from heavy grazing which is statistically different from that of light/moderate grazing. Runoff and sediment yield decreased with reduced grazing in a long term study of grazed and ungrazed areas (Lusby, 1979). Over the first 12 year period, elimination of grazing resulted in a 25% reduction of runoff, accompanied by a simultaneous reduction in sediment yield of approximately 35%. In the subsequent seven year period, ungrazed areas yielded 60% of runoff and 37% of sediment produced under the original grazing program.

The stream channel, stream banks, and beneficial uses of water are impacted by these hydrologic effects. Increased runoff increases upland sheet and rill erosion, resulting in stream sedimentation. Increased peak runoff also increases stream energy for bank erosion, downcutting, and gully formation. Reductions in water infiltration and storage reduce the magnitude and duration of low flows. Decreased discharge from storage during the summer reduces habitat space and water quality for maintaining the aquatic community during this critical period.

GRAZING IMPACTS ON THE RIPARIAN ZONE

Riparian zones are often grazed more heavily than upland zones because they have flatter terrain, water, shade, and more succulent vegetation. Livestock grazing can affect the riparian environment by changing, reducing, or eliminating riparian areas through channel widening, channel aggrading, or lowering of the water table. Generally, in grazed areas, stream channels contain more fine sediment, streambanks are more unstable, banks are less undercut, and summer water temperatures are higher than streams in ungrazed areas. These conditions result in reduced salmonid populations (Platts, 1991).

Temperature and canopy

Temperature increases in streams when grazing reduces canopy or overhanging bank vegetation, contributes to channel widening and shallowing, or reduces summer low flows. In western North America, streams that have lost their vegetation or have had a change in riparian plant forms (e.g., from brush to grass) are often too warm in the summer to support salmonid populations. Platts (1991) speculates that increases in temperature due to reduced streamside vegetation could partially explain the gradual shift from salmonids to nongame fish in many western streams.

Binns (1979) found that maximum summer temperature was one of nine parameters in a habitat quality index that explained 96% of the variation in trout standing crop in Wyoming streams. Platts and Nelson (1989) found a high correlation between thermal input and salmonid biomass in the Great Basin; in the Rocky Mountains the relationship was not significant.

Streams can also be too cold for successful trout survival. If temperature falls low enough, anchor ice can form on the bottom of the stream. Streams with little or no vegetative canopy are very susceptible to the formation of anchor ice (Platts, 1991). Vegetative cover also helps moderate winter temperatures reducing heat loss from the earth.

Stream channels

Stream channels and stream flow determine the living space available for salmonids. Stream channels altered by grazing become wider and shallower, reducing salmonid living space. Several papers have related salmonid abundance to water width, depth, pools, and stream flow (Marcus et al., 1990; Binns, 1979). Kozel and Hubert (1989) found that width-to-depth ratios, average stream width, and level of late summer stream flow were highly correlated with trout biomass. Stream depth explained most of the variation in trout biomass in headwater streams in central Arizona (Rinne and Medina, 1988). In the Wyoming habitat quality index, annual stream flow variation was highly correlated to trout biomass (Binns, 1979).

Channel downcutting caused by riparian degradation lowers local water tables and reduces the volume of base stream flow during the critical summer period. Such reductions in low flow increase annual stream flow variation.

Sedimentation can also reduce the amount of salmonid habitat. Sediment in grazed watersheds is derived from upland and streambank erosion. Fine sediment fills the interstitial spaces between coarser particles and fills in pools, reducing available habitat for fish and aquatic invertebrates. Although these impacts have been documented, it is difficult to establish quantitative criteria (Chapman and McLeod, 1987) and the relationship between sediment and salmonids is difficult to define (Everest et al., 1987).

Stream banks and streamside vegetation

Streambank stability is directly related to the quality of streamside vegetation. During high water, streamside vegetation protects the banks from erosion, reducing water velocity along the stream edge, and causing stream sediments to settle out.

Platts (1991) has summarized the importance of streamside vegetation in providing cover and maintaining streambank stability. Trees provide shade and streambank stability because of their large size and massive root systems. Trees that fall into or across streams create high-quality pools and contribute to channel stability. Brush protects the streambank from water erosion and its low overhanging height adds cover that is used by fish. Grasses form the vegetative mats and sod banks that reduce surface erosion and mass wasting of stream banks. As well-sodded banks gradually erode, they create the undercuts important to salmonids as hiding cover. Root systems of grasses and other plants trap sediment to help rebuild damaged banks.

When animals graze directly on streambanks, mass wasting from trampling, hoof slide, and streambank collapse causes soil to move directly into the stream. Excessive grazing on streamside vegetation reduces the ability of vegetation to protect streambanks and trap sediments.

The effect of grazing on streambanks depends on site conditions, management practices, and interaction with other factors. Kauffman et al. (1983) found that late-season grazing increased bank erosion relative to ungrazed areas. Platts (1981) documented stream bank and stream channel damage where sheep were concentrated in a riparian zone. Riparian vegetation, streambanks, and stream channel conditions improved when grazing was prohibited in an exclosure (Platts and Nelson, 1985).

Other factors may also reduce streambank stability. Buckhouse (1986) lists studies where bank damage was attributed to high runoff flows and ice flows in addition to grazing. In Meadow Creek, season-long grazing was associated with bank sloughing, but bank damage was also attributed to severe ice floes (Buckhouse, 1986).

SALMONID REQUIREMENTS

Salmonids, including trout, salmon, and chars, require high quality waters and therefore serve as good indicators of quality aquatic environments. The water quality and habitat requirements of salmonids, shown in Table 2.2, may be altered by livestock grazing. Salmonids require low temperatures, high dissolved oxygen concentrations, clean substrates, sufficient water depth and velocity, and hiding and escape cover.

Trout are particularly sensitive to temperature when spawning, with recommended temperatures in the range of 5 - 14° C. Optimum temperatures for rearing are in the 14-16 °C range. Salmonids are placed in life-threatening conditions when temperatures exceed 23-25 °C. Most state water quality standards specify temperature criteria less than these extremes for protection of cold water biota.

Table 2.2. Critical habitat requirements for salmonids and contributing factors (based on Bjornn and Reiser, 1991)

Adult migration

- Stream temperature - streamside shading, stream width, width/depth ratio, stream flow
- Dissolved oxygen - temperature, BOD, nutrients, stream flow
- Turbidity - surface and stream bank erosion
- Stream flow - dewatering, width/depth ratio, stream width

Spawning

- Stream flow - dewatering, width/depth ratio, stream width
- Stream temperature - streamside shading, stream width, width/depth ratio, stream flow
- Spawning habitat quantity - pool/riffle ratio, gradient, substrate
- Water depth and velocity - depth, velocity, stream flow
- Substrate - surface fines, substrate composition
- Cover - overhanging vegetation, undercut bank, submerged cover (i.e. vegetation, logs, and rocks), water depth, turbulence

Incubation

- Substrate - surface and depth fines, substrate composition
- Intragravel oxygen - temperature, BOD, nutrients, stream flow
- Stream temperature - streamside shading, stream width, width/depth ratio, stream flow

Rearing (juvenile and adults)

- Stream temperature - streamside shading, stream width, width/depth ratio, stream flow
- Dissolved oxygen - temperature, BOD, nutrients, stream flow
- Turbidity - surface and stream bank erosion
- Productivity - nutrients, primary and secondary production (food), energy inputs (sunlight and detritus)
- Living space - stream flow, stream width, width/depth ratio, gradient, velocity, instream and riparian cover
- Cover - water depth, water turbulence, large particle substrate, undercut banks, overhanging riparian vegetation, woody debris, aquatic vegetation

Low dissolved oxygen concentrations affect growth, food conversion efficiency, swimming performance, and survival. Incubation of embryos and emergence to fry are the most sensitive stages. Recommended levels for successful incubation are at or near saturation with temporary reductions in dissolved oxygen no lower than 5 mg/l (Bjornn and Reiser, 1991).

High turbidity reduces sight feeding and growth and interferes with migration. Salmonid sight feeding is impaired at turbidities in the range of 25-70 NTU. Salmonids will migrate in water of higher turbidity; however, they avoid such waters for rearing and feeding (Lloyd et al., 1987). Recommended levels to protect salmonids is 50 NTU, measured instantaneously, or 25 NTU, measured over a ten day period (Harvey, 1989).

Clean substrates are important habitat components because salmonids build nests (redds) in gravel and cobble substrate. Clean substrates are required to provide dissolved oxygen to the embryo, remove metabolic wastes, and allow alevins (fry) to emerge from the redd. Sediment from erosion reduces the survival of embryos.

During spawning, salmonids also need adequate cover for escape and hiding. This cover is provided by overhanging vegetation, undercut banks, submerged vegetation, submerged objects such as logs and rocks, attached floating debris, deep water, turbulence, and turbidity.

Stream flow is also important, because it determines the amount of spawning area available by regulating the area covered by water and the velocity and depth of water over the gravel beds. Preferred water depth and velocity have been established for many species. Grazing management practices often alter the hydrologic regime by increasing peak flows and decreasing base flows. These changes decrease the amount of habitat available for salmonids at critical times in their life cycle.

Streams with a diversity of habitats support high salmonids populations. Living space for salmonids is a function of stream flow, channel morphology, gradient, and instream and riparian cover. Habitat diversity is created by deep pools with structures such as boulders, sunken logs, and root wads, and by undercut banks with overhanging vegetation. Channels with high sinuosity and a variety of pools, runs, and riffles also contribute to diversity.

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III. MONITORING PLAN PROCEDURE

The following section provides an overview of monitoring plan development and a discussion of the types of monitoring strategies that can be used. Each step in developing a monitoring plan is then described.

OVERVIEW OF MONITORING STEPS

A watershed project is initially proposed to correct a perceived or documented water quality problem. Water quality problems should be defined in terms of measurable stream variables or stream attributes. Monitoring needs to detect changes due to management separate from changes attributed to natural variability. The object of monitoring planning and design is to select those key variables at representative sites that are expected to respond to management. Selection of key variables involves a sorting process, based on the watershed project objectives and considering the realistic constraints of monitoring.

The development of a monitoring plan includes compiling existing information and gathering data from a field reconnaissance to focus the scope of monitoring. These questions should be considered throughout the planning process.

- What are the issues and concerns that started the project?
- What are the beneficial uses of water in the stream? (Waterbodies have designated beneficial uses. These are listed in the state water quality standards.)
- What are the potential limiting factors for the sensitive beneficial uses?
- Are these limiting factors influenced by grazing and/or other nonpoint source activities in the drainage?
- What is currently known about the existing stream condition?
- What additional information is needed to make an assessment of existing stream condition and cause and effect?
- Of the potential stream/riparian variables, which key variables are expected to respond to project management?
- What are the monitoring project constraints in terms of budget, personnel availability, expertise, site conditions, and other factors?

The planning steps shown in Table 3.1 comprise a process of gathering and evaluating cursory information to assist in answering these questions and then designing a responsive monitoring program. A discussion of each of these steps follows.

Table 3.1. Steps in developing the monitoring program

1. Identify issues and concerns.
2. Stratify and classify stream reaches (initial classification).
3. Conduct reconnaissance: Assess existing conditions, refine water quality issues, and complete stream classification.
4. Establish specific goals and objectives.
5. Select parameters and monitoring design.
6. Select representative monitoring and reference sites.
7. Conduct first year or pilot project monitoring.
8. Reassess assumptions and objectives and modify monitoring plan.

IDENTIFY ISSUES AND CONCERNS

Water quality issues and concerns are formulated with program managers, project sponsors, cooperating agencies, and interested public. The status of the beneficial uses is a primary issue. The stream may be unsuitable for swimming or the fishery may have declined. Designated benificial uses for a particular water body are listed with a state's water quality standards. Issues may also include an analysis of the resources available to conduct monitoring, such as budget, personnel, equipment, and laboratory costs.

General project goals are formulated. These goals provide the framework for organizing and reviewing existing data and selecting the approach for conducting the field reconnaissance. Project goals should include an identification of the geographic area of interest, the beneficial uses of concern, and the impact of grazing on the beneficial uses. These assumptions will be evaluated in the field and as part of the first year of monitoring.

A goal is considered the overall aim or endpoint of the project. Objectives are a subset of project goals; one goal may have multiple objectives. Project goals may be expressed qualitatively, but objectives are expressed in quantitative terms. Examples of goal and objective statements are presented in Table 3.2. The general issues and concerns provide the sideboards for stratifying stream reaches and collecting additional information.

Table 3.2. Sample monitoring plan goals and objectives

Goal:	Improve water quality to support cold water fisheries.
Objective:	Increase riparian vegetation to assure that average daily temperature remains below 19° C during the summer.
Goal:	Improve streambank cover and stability to decrease bank erosion.
Objective:	Increase vegetative cover on streambanks so that 80-90% of the banks are rated as covered and stable.

Specific objectives for monitoring are formulated based on a comparison of the existing condition to the expected condition. The potential for the project to influence measurable stream attributes within a reasonable time frame is assessed.

STRATIFY AND CLASSIFY STREAM REACHES

Physical, chemical, and biological attributes of streams vary between watersheds because of differences in climate, hydrology, geology, landform, vegetation, and soils. Streams vary along their length as changes occur in gradient, channel substrate, sinuosity, stream size, and riparian vegetation. Stream types described by classification systems exhibit differential response to a given management activity. The ability to predict a response is an important objective of stream classification. Classification allows identification of representative monitoring sites and reference stations.

Streams are classified in two stages following the methods described in the Integrated Riparian Evaluation Guide (USDA Forest Service, 1992). The initial classification is an office procedure that uses existing information - aerial photographs, topographic maps, soil surveys - to identify stream reaches. This initial stream stratification provides a basis for organizing collection of data during the reconnaissance phase. Field data collected during reconnaissance is used to adjust reach boundaries and complete the stream classification.

Stream reaches are classified on the basis of three criteria - soils/parent geology, dominant riparian vegetation, and stream type (Table 3.3). Stream types are classified by measurable morphological features as described by Rosgen (1993) and summarized in Appendix B. An alternative stream classification system based on geomorphology is described by Montgomery and Buffington (1993).

The Rosgen classification system results in a designation (A, B, C etc.) that describes stream channel morphology. For example, a C3 stream type is a low-gradient meadow stream with high sinuosity and a predominantly cobble substrate and an A1 stream type is an entrenched stream with low sinuosity and a bedrock substrate. The stream type classification can be used to identify potential reference areas with a similar morphology.

Soil type and riparian vegetation communities are the other components of stream reach classification. Soil family mapping units from a soil survey are used to delineate major differences in soil capability. Riparian vegetation is identified by community type. Community types are named on the basis of the dominant overstory species and the dominant or most characteristic undergrowth species. Soil type, riparian community type, and Rosgen stream type provide a useful method to stratify streams for the purpose of locating monitoring stations.

Stream reaches can be divided further into subreaches based on land use or land ownership. These subreaches distinguish the differences in administration and management that will affect project implementation. Monitoring sites are located within selected subreaches based on project objectives.

Table 3.3. Stream classification hierarchy

TRIBUTARY

I. STREAM REACH
- Soils/parent Geology
- Dominant riparian community
- Rosgen stream type
  - gradient
  - sinuosity
  - channel width/depth ratio
  - dominant particle size
  - valley bottom type

II. SUB-REACH
- Land ownership
- Land use

III. MONITORING SITE
- Hydraulic pattern
  - slow water - pools and glides
  - fast water - riffles and runs

CONDUCT RECONNAISSANCE: EVALUATE EXISTING CONDITION AND IDENTIFY POTENTIAL LIMITING FACTORS

Field reconnaissance completes identification of stream reaches and identifies riparian communities. The field reconnaissance also provides a qualitative evaluation of the existing stream condition and a determination of possible causes and effects of water quality degradation. The objective of this phase is to identify those factors which are thought to limit the beneficial uses. Limiting factors are stream attributes which prevent the full attainment of the beneficial uses. For example, high summertime temperatures, lack of suitable spawning gravel, or lack of pools and hiding cover may limit fish populations.

Potential limiting factors are evaluated in the field by qualitative measurements and professional judgement. Table 3.4 lists potential limiting factors and describes the reconnaissance evaluation techniques. Each stream attribute is discussed in more detail in the following sections.

Table 3.4. Potential water quality parameters/limiting factors identified through field reconnaissance

Water Quality/Riparian Parameter	Reconnaissance Evaluation
Water Column	
1. Temperature	Indirect from vegetative shade and width/depth relationship.
2. Shade	Ocular estimate of canopy cover.
3. Nutrients	Ocular estimate of algae/aquatic plant growth.
4. Fecal contamination	Observation of fecal material in and near the stream channel.
5. Flow modifications	Width/depth measurements, observation of dewatered channels.
Stream Channel/Streambanks	
6. Streambank stability	Estimates of cover and stability.
7. Bank undercut	Estimate of bank undercut.
8. Overhanging Vegetation	Estimate of vegetative overhang.
9. Channel morphology	Measured bankfull and water surface width/depths.
10. Pool quality	Estimate of % of pools, pool depth, or pool quality rating.
11. Substrate sedimentation	Estimates of substrate composition (percent sand, gravel, cobble, etc.) Ocular estimate of embeddedness.
Streambank Vegetation	
12. Plant species composition	Identification of riparian community types.
13. Woody species health	Observation of woody species age classes.
14. Streamside utilization.	Ocular estimate of utilization near streambanks.
Biological Assessment	
15. Macroinvertebrate community	EPA rapid bioassessment protocols, RBP I or II.
16. Fish community	EPA rapid bioassessment protocols, RBP IV or RBP V (qualitative sample).

Water column

During reconnaissance, temperature, nutrients, and bacterial impacts are evaluated indirectly by observation of stream conditions. This evaluation can be improved by including a limited number of grab samples. Temperature conditions are evaluated by observation of the amount of stream surface area exposed to solar radiation. Wide and shallow streams with little shading would be expected to experience high summer temperatures. Maximum registering thermometers can be used during a reconnaissance to better assess high temperatures before deciding whether to monitor temperature with recording thermographs.

The potential for bacterial contamination is assessed by observation of fecal material within the stream channel and adjacent riparian area. Fecal matter can enter the stream during a runoff event. Grab samples can provide additional information for assessment of fecal coliform bacteria. Results of the grab samples are evaluated by relating the time of collection to recent livestock use in the area.

Algal/aquatic plant growth is stimulated by low concentrations of nutrients. Potential nutrient input is assessed at the reconnaissance level by observation of livestock wastes within the stream channel. Grab samples for nutrients can be collected to provide additional information. Total Phosphorus and Total Nitrate + Nitrite will generally provide sufficient information. Nutrient concentrations are determined by laboratory analysis of a water sample. Because nutrients are quickly cycled within a system, grab samples collected during low flows may be of limited value.

Stream channel and stream bank condition

Alteration of stream banks and stream channels are the most widespread impacts from grazing. These changes can be caused by direct livestock activity or by alterations in the watershed from grazing. Grazing on the uplands may alter the supply of sediment and the flow regime causing readjustment in channel shape and scouring and deposition of sediment.

Overgrazing in the riparian zone may contribute to bank instability and reduce bank cover, causing an increase in bank erosion. Stream channel shape adjusts to these impacts by widening and becoming more shallow or the channel downcuts, lowering the water table and reducing the extent of the riparian zone. Sediment from upland and channel erosion also changes stream bottom composition and increases the percentage of fines. Available habitat space decreases as the stream is altered from a narrow and deep channel to a wide and shallow channel.

The critical attributes to consider include channel morphology, streambank stability, vegetative overhang, streambank undercutting, substrate sedimentation, and pool quality. Streambank undercuts and overhanging vegetation provide protective cover, shade for temperature control, and a supply of terrestrial insects as food for fish. Determining percent of the streambank that is stable, covered by vegetation, undercut, or has overhanging vegetation is done by ocular estimates, pacing, or measurements at representative locations.

Substrate composition provides information on in-stream hiding cover, quality of spawning substrate, and production of insects. Ocular estimates are made of substrate composition and embeddedness. Pebble counts, which are relatively quick and easy, may be used to improve estimates of substrate composition.

Stream channel morphology is usually measured by establishing permanent cross sections. Channel characteristics evaluated at each cross section include bankfull width and depth, low flow width and depth, width/depth ratio, and cross sectional area. Estimates are also made of the occurrence of pools and rating of pool quality.

Streambank vegetation

Streambank vegetation provides cover for fish, shades the stream to maintain temperature, and provides habitat for terrestrial insects utilized by fish. Streamside vegetation is the primary tool available to the manager to stabilize stream banks and restore natural channel features. The roots of riparian plants, such as willow and sedge, hold the soil together to resist erosion. The vegetative mat along the stream traps sediment during high water to build banks and increase plant production and vigor.

The three areas of concern include vegetative composition, woody species regeneration, and vegetative utilization. Vegetative composition is evaluated by sampling community type composition along the "green line." The green line is the area adjacent to the stream where more or less continuous cover of perennial vegetation is encountered (USFS, 1992). The length of each vegetation community type encountered along the green line is tallied and the community composition is compared to the potential natural community composition.

Woody species regeneration is evaluated on those riparian sites that are suited to growth of woody species. Overgrazing reduces regeneration by cropping sprouts and young plants and results in a plant community dominated by a few older or dying plants. Woody species regeneration is evaluated along the green line transect by tallying the number of plants that occur in age classes: sprout, young, early mature, late mature. Age class is determined by counting the number of stems. The method of counting stems is modified depending on the species of woody plant.

Measuring vegetation utilization along the stream bank provides information on the linkage between grazing and protection of stream banks. A residual amount of vegetation is needed at the end of the growing season to protect streambanks during high flows in the spring. Herbage utilization can be measured using a number of methods familiar to the range specialist such as measured or estimated stubble height along a transect or biomass, as determined from a grazed and ungrazed area.

Biological assessment

A biological evaluation is a direct measure of macroinvertebrate and fish communities. These communities reflect the quality of the stream environment over time by integrating the effects of the water quality and habitat factors. Benthic macroinvertebrate communities are good indicators of localized conditions and respond fairly rapidly to changes in the environment. Fish are indicators of long-term effects and broad habitat conditions because they are long-lived and mobile.

Rapid Bioassessment Protocols (RBP) can supplement the aquatic habitat parameters by providing an estimate of the health of the aquatic community (Plafkin et al., 1989). Protocol I is a screening assessment which uses field identification of benthic macroinvertebrates to the order/family level. Impairment is indicated by the absence of pollution sensitive taxa such as stoneflies, mayflies, and caddisflies; the dominance of pollution-tolerant groups; or overall low abundance and taxa richness. Protocol II is a more intensive assessment using kick net samples. Subsamples are sorted and counted, allowing for the use of additional metrics and the Index of Biotic Integrity.

A reconnaissance level survey of the fish community can be made using one-pass snorkeling or electrofishing. Fish are identified to the species level; classified as adult, juvenile, or young of the year; and counted. This level of effort provides information on relative abundance of fish species and status of natural reproduction. This data can be used to calculate the Index of Biotic Integrity described in protocol V (Plafkin et al., 1989).

The field reconnaissance will provide some answers as well as raise additional questions about the initial assumptions of the cause and effect of pollution. Additional inventories or a pilot water quality study may be needed to answer these questions before completing a study design. The first year of monitoring can be considered a pilot study, with revision of the study design based on the initial data set.

ESTABLISH SPECIFIC GOALS AND OBJECTIVES

The identification of potential water quality limiting factors provides the basis for development of monitoring objectives. It is important to evaluate which of these factors result primarily from grazing and will respond to project implementation before developing project goals and objectives.

Monitoring objectives are developed by:

1. Identifying the existing condition and potential limiting factors,
2. Determining if grazing is the causative agent and whether the proposed project will reduce the limiting factor;
3. Determining survey limitations; and
4. Identifying the desired condition for key variables.

During the initial planning stage, the existing condition and potential limiting factors are evaluated through review of existing data and field reconnaissance. Limiting factors include both direct factors, such as temperature, and indirect factors. Streamside vegetation has an indirect influence on temperature through the reduction in stream shading. Most of these issues are interrelated; streamside vegetation provides shade and cover, water filtering effects for overland flow, and root strength to protect bank stability. In considering monitoring objectives, it is important to consider the overlap among variables. The scope of monitoring should be limited to a few key variables that will provide the most information.

The impacts of other nonpoint source activities and natural conditions should also be evaluated. Are other nonpoint source activities causing an observed impact? Do upstream pollution sources influence water quality to the extent they mask any improvement from the grazing project?

It may not be possible to account for the effects of upstream sources on water column or stream channel parameters in the monitoring program. For example, an upstream source of sediment may control substrate composition and pool depth in the study reach. Instead of monitoring substrate sedimentation and pool filling, more useful data might be obtained by monitoring a parameter which responds directly to localized improvement, such as streambank characteristics. There is no simple method to sort out impacts from different nonpoint sources, but awareness of multiple sources can prevent collection of meaningless data.

Water quality projects depend primarily on changes in grazing management to improve watershed condition and restore stream channel stability. Strategies for protecting or restoring riparian areas may incorporate 1) utilization of riparian pastures, 2) fencing or herding livestock out of riparian areas to allow streambanks to recover, 3) controlling the timing of grazing to protect streambanks or coincide with the physiological needs of the target plant species, 4) adding more rest to the grazing cycle, 5) limiting grazing intensity to maintain riparian species composition and vigor, 6) changing the kind of livestock from cattle to sheep, 7) moving livestock from the allotment once target livestock utilization levels for herbaceous and woody vegetation are reached, and 8) permanently excluding livestock from riparian areas at risk while grazing adjacent uplands, when there is no other practical way to protect these areas (Chaney et al., 1991).

Project strategies should be considered when selecting monitoring sites, establishing duration of monitoring to correspond to the expected recovery period, and selecting monitoring variables that will be responsive to the project. The ability to detect change in the stream/riparian attributes will influence project objectives.

Practical problems may exclude certain monitoring objectives. For instance, road conditions can prevent access during high flows. In this case, flow dependent parameters, such as suspended sediment, turbidity, and nutrients, will not be useful unless automatic samplers are used. Field evaluations may require expertise that is not available. An individual with biological experience is needed to use Rapid Bioassessment Protocols for macroinvertebrates because this method includes field identification to family or generic levels. An adequate budget is needed to cover laboratory costs, equipment purchase, and personnel time. These practical considerations may eliminate inclusion of certain water quality objectives because they can not be effectively evaluated.

Establishing monitoring objectives also requires an identification of the desired condition. The desired condition may be defined in terms of established water quality criteria, site-specific reference areas, regional reference conditions, or a combination of these methods.

Recommended water quality criteria have been identified for some of the limiting factors listed in Table 3.4.: temperature thresholds for warm water and cold water fish, fecal coliform bacteria limits for recreational use of water, and advisory limits for nutrients in streams based on eutrophication (EPA, 1986). Criteria for temperature and fecal bacteria have been adopted in state water quality standards and are useful in establishing project objectives. Numerical standards for nutrients in streams have generally not been adopted.

For the majority of stream bank and channel factors listed in Table 3.4, state numerical water quality standards have not been adopted. Narrative standards which address limiting factors qualitatively may apply. Setting objectives for these factors can be based on a comparison of parameters in the project area to site-specific or regional reference sites. When site-specific reference areas are used, the measurable objectives are based on similarity indices.

When site-specific reference sites can not be located for the project, the objectives may be based on a range of desired conditions determined from a number of reference sites. This process is one method used in USDA Forest Service planning to establish the Desired Future Condition (DFC) of aquatic habitat. Potential stream conditions are determined by completing inventories of streams that are considered unimpacted by human activity. The mean and numeric range of conditions from these areas are used as the benchmark in developing objectives for the project area.

SELECT PARAMETERS AND MONITORING DESIGN

Monitoring parameters

Grazing, other nonpoint source activities and natural processes affect the riparian ecosystem in a complex manner. Different procedures to measure these effects have been developed and continue to evolve as professionals apply the methods under various field conditions.

A number of factors must be considered when choosing monitoring parameters. These are discussed below. An overall monitoring design must also be specified. The alternative designs are presented later in this section.

Considerations when selecting parameters

Many traditional water column parameters may be influenced by grazing, but these parameters are flow dependent, and hence difficult to sample under conditions typically encountered in range lands. Automatic samplers are an alternative, but are rarely used by management agencies due to cost, vandalism, and maintenance requirements.

The preferred parameters are those that are measured at low frequency during the summer base flow period. These parameters reflect the condition of the stream and riparian area as a result of the yearly cycle of runoff, stream channel response, vegetative growth, and nonpoint source impacts. Because of low flows and high temperatures, summer is considered a critical period for cold water biota.

Many agencies either have in-house methods or are in the process of developing methods. This document is not intended to take the place of other agency protocols, but to describe a set of tools that may be useful in documenting water quality impacts and improvements.

During planning, the recommended sample frequency, estimated collection time, laboratory process cost, specialized equipment needs, and expertise needed for each parameter is evaluated. Generally, methods which depend on observed ratings require experienced professionals to make the necessary judgement calls. When considering a method, the ease of data collection should be balanced against the ability to detect change, given the method's precision and accuracy. Riparian systems exhibit high natural variability, which affects an ability to detect treatment differences. The example in Table 3.5 will clarify necessary planning considerations.

Table 3.5. Bear Valley Creek; An example in monitoring design

Background: Bear Valley Creek is located in the headwaters of the Middle Fork Salmon River on the Boise National Forest in Idaho. A portion of the creek is located in a wilderness area. This high elevation valley is mostly forested with meadows along the streams. These meadows provide summer forage for cattle.

The low gradient streams in Bear Valley have the potential to provide ideal spawning and rearing conditions for spring chinook salmon. The decline of salmon in the drainage has been attributed to downstream impacts on migration and to poor habitat conditions related to grazing, mining, and logging impacts. A dredge mining operation historically contributed massive sediment loads to the stream, but this area has been stabilized to reduce sediment inputs. Logging road networks are minimal and future timber harvests has been designed to result in a net decrease in sediment through road stabilization and road closures. Grazing in the meadows adjacent to the stream channels is thought to be the current major impact.

Existing condition/ limiting factor analysis: To determine habitat factors contributing to the decline of salmon, fish densities and habitat conditions were measured in Bear Valley Creek and nearby unimpacted streams. It was determined that spawning and rearing habitat quality had been significantly reduced by large amounts of fine sand. The bedload sediment was filling pools and altering stream substrates. This impaired egg incubation and rearing of fry and juveniles. Survival of young salmon in Bear Valley Creek was only one tenth of survival in the reference areas and substrate percent fine sediment was two to four times greater than in the reference streams.

Analysis of impacts: Habitat variables were measured at numerous impacted and unimpacted stream reaches to evaluate cause and effect. Both within and outside the wilderness area, stream reaches associated with cattle grazing were correlated to habitat degradation. Habitat quality was reduced by bank destabilization from shearing and sloughing and changes in riparian plant species composition. On the average, stable streambanks were observed half as often as in unimpacted reference streams, and substrate fine sediment was higher in unstable reaches. Unimpacted reference streambanks had higher densities of hydric plant communities than impacted streambanks. Trailing and trampling altered plant species composition and reduced the amount of deep-rooted hydric vegetation. The plant species alteration likely weakened the streambanks leading to eventual collapse and slumping into the stream. Such erosion increased fine sediments instream.

Desired Future Condition: Data from unimpacted reference streams provided information to develop project goals and monitoring objectives. Desired future condition was defined in terms of riparian vegetative composition, substrate fine sediment, and bank stability and cover. Grazing management has been modified to include riparian pastures, corridor fencing, herding to modify livestock distribution, and changes in season of use.

Parameter selection: Direct streambank modification was determined to be the primary detrimental effect of grazing. Bank stability and cover were selected as the key parameters. Numerous stations were randomly established to monitor stream bank stability and cover before, during, and after the grazing season. Prior to grazing, bank stability/cover ratings are established for 50 meters on each streambank at each station. Ratings are made in increments of 0.5 meters. Subsequent ratings, three per season, are made in direct comparison to the initial rating. This is very sensitive measure of change due to grazing and an effective management tool.

Other parameters measured at selected stations include forage utilization adjacent to stream banks, Green Line vegetative composition, and woody species regeneration. Idaho Fish and Game monitors redd numbers, juvenile survival, and surface fine sediment. These additional parameters provide information for ongoing evaluation of cause, effect and improvement in the beneficial uses.

Monitoring design

Monitoring design is discussed briefly below. See McDonald et al. (1991) for a brief review of statistical considerations in nonpoint source water quality monitoring. More extensive review of experimental design and data analysis is provided in texts on statistics (Conover, 1980; Gilbert, 1987; Green, 1979; Stednick 1991, Ward et al. 1990, Zar, 1984).

Monitoring design refers to the overall strategy for locating stations and developing the approach to data analysis and interpretation. Common water quality monitoring designs include Reference Area, Paired Watershed, Above and Below, and Before and After.

The following discussion of each type of monitoring design describes factors to be considered in the selection process. A monitoring design may depend on a particular design or may incorporate a combination of these approaches.

For the evaluation of grazing impacts, the **Reference Area Design** is the preferred approach. The EPA Nonpoint Source Manager's Guide recommends comparative monitoring of project stations to reference sites as the most effective design for detecting treatment effects (Coffey and Smolen, 1991).

Reference areas are stream reaches that contain habitat of sufficient quality to maintain biological integrity. Biological integrity has been defined as:

> The condition of the aquatic community inhabiting the unimpaired waterbodies of a specified habitat as measured by community structure and function (EPA, 1990).

The reference area design can be used when suitable reference sites for the project area can be located. Reference areas provide a control for determining background effects related to weather and hydrologic events. The reference area can also be used to develop objectives for the project watershed by providing data to describe the potential desired condition.

Identifying reference sites is not a simple task on rangelands that have been historically used for grazing. The reference site may have experienced some level of impact, but still represents a habitat that supports an aquatic community in good to excellent condition. In practice, reference sites are chosen that reflect the least impacted conditions possible.

Reference areas may be incorporated into the study as site-specific reference sites or as reference sites that describe the regional reference condition. **Site-specific reference sites** are identified within the same drainage or nearby drainage and will be sampled at the same time as the study site. This accounts for variability due to factors other than grazing. Storms, drought, temperature extremes, ice flows, and wildlife activity are examples of variables, in addition to grazing, that can affect water quality. Although no perfect match exists, monitoring reference sites will help distinguish the impacts of grazing from other impacts.

The second approach for identifying reference conditions utilizes **regional reference sites**. A regional framework provides boundaries around areas where environmental conditions are relatively homogenous as compared with other areas (Gallant et al., 1989). A map for assessing surface waters using this approach, Ecoregions of the Conterminous United States (Omernik, 1987) was based on land surface form, potential natural vegetation, soils, land use, and other environmental factors. Multi-state maps showing greater detail are available at a scale of 1:2,500,000 (Omernik and Gallant, 1986, 1987a, 1987b, 1987c, 1988). These ecoregional frameworks have been used for regional biocriteria in Ohio's water quality program and for regional lake management in Minnesota (Gallant et al., 1989).

Western states are in the process of evaluating or developing ecoregional reference sites as the basis for biological criteria (EPA, 1991a). The delineation of ecoregions and subregions, identification of reference sites, and collection of associated physical and chemical data provide a data base for defining local reference conditions. In some ecoregions, the area may be so impacted that no or few suitable reference sites exist (Hughes et al., 1990). In these cases, reference areas from similar sites in other regions may need to be considered.

Desired Future Condition (DFC) is a procedure similar to ecoregional references. This approach is being used by the USDA Forest Service in land management planning. The DFC for a habitat parameter is based on measured data from reference sites in unimpacted areas or from research which defines habitat quality requirements. The DFC is similar to Potential Natural Community of Climax Community used in most ecological classification systems. These terms all refer to what is an successionally advanced or reachable condition.

Typically many reference areas are used to describe the range of conditions. The desired future condition identified for management purposes is not equivalent to a reference site. The reference sites are used as benchmarks to identify the natural potential on which the DFC is based. As an objective, the DFC may be identified as some percentage of the reference site that meets the biological requirements and objectives. Since there have been extensive efforts to define DFC in western national forests, this information may be a valuable reference for defining objectives for selected parameters in a project area.

An advantage of the reference area design is that it provides information for establishing measurable project objectives on a site-specific or regional basis. Management goals and objectives are based on achieving conditions similar to the reference area or some percentage of the reference area. The data may be analyzed using a similarity index or the percent of the project parameter that is similar to the reference site.

The **Paired Watershed Design** involves monitoring two comparable watersheds over time; one watershed receives treatment and the other does not. In evaluating agricultural watershed projects, Spooner et al. (1985) suggested that paired watershed designs have the greatest potential for documenting improvements from Best Management Practice (BMP) implementation because you can account for meteorologic and hydrologic variability.

EPA recommended the paired watershed strategy for projects participating in the National NPS Monitoring Program (EPA, 1991b). These studies measured primarily water column parameters, such as nutrients and suspended sediment, which are flow dependent and require frequent samples to account for the high variability. The paired watershed design may be appropriate where the primary objectives focus on water column parameters. However, monitoring high flows is usually infeasible unless automatic samplers are used.

Above and Below design involves sampling a stream upstream and downstream from a nonpoint source activity. This design is useful where there is a distinct boundary between the upstream and downstream segment or above and below the entry of a tributary. This design works better with water column parameters rather than habitat parameters. Sampling should encompass the runoff period when pollutants enter the stream. This design is usually not effective for rangeland watersheds since land use activity is rarely defined by distinct segment boundaries, pollutant entry during runoff tends to mask any upstream - downstream differences, and access is often difficult during high flow periods.

Before and After Design is characterized by monitoring of sites prior to project implementation and for some period of time after implementation. The design can be applied to both water column and habitat parameters. Climatic and hydrologic variables are not accounted for by this approach, so long periods of monitoring before and after project implementation are needed to detect changes (Spooner et al., 1985).

SELECT MONITORING SITES

Stream reaches are identified on the basis of stream type and riparian community type. The number of unique stream reaches that will be monitored is determined and representative monitoring sites are established within those reaches. Monitoring sites selected should be representative of the composition of macro-habitats (riffle/run/pool) that occur within the stream reach. The stream reach classification provides a basis for identifying comparable reference reaches or regional reference conditions.

Monitoring sites are designated differently for water column and stream channel parameters. The monitoring site is a single point where a grab sample is collected or a cross section from which depth-integrated samples are collected for water column parameters. For stream channel and streambank parameters, a monitoring site consists of a representative stream reach divided into multiple transects. The transects provide a means of collecting replicates for stream channel and stream bank parameters.

Selection of monitoring sites is a function of objectives, monitoring design, access, and budgets. Stream classification provides a systematic way to identify stream reaches which are expected to respond to management in a similar manner.

The recommended sampling strategy uses a modification of the stratified-systematic approach to divide the stream into non-overlapping strata, each strata being the stream reach or subreach (Gilbert, 1987). Systematic sampling results in measurements according to a spatial pattern of equidistant intervals along the stream channel. Since individual strata, the stream reaches, are often too large in practice, the suggested approach is to select a representative monitoring site within the reach based on hydraulic characteristics.

The stream is divided into designated stream reaches on the basis of natural features (morphology, soils, community type) and into sub-reaches on the basis of land use. Within a designated reach, there is a characteristic pattern of hydraulic units: fast water (riffles and runs) and slow water (pools and glides). Sampling within the reach occurs in proportion to these units since changing velocity and depth affects many stream channel parameters. To select a representative reach, the occurrence of fast and slow waters in the stream reach is mapped and the proportion of fast and slow waters is calculated. A representative reach is selected that has a similar riffle to pool pattern as that calculated for the stream reach.

The length of stream reach and the number of transects recommended for sampling depends on site variability and desired precision. The recommended reach length is in multiples of the bankfull width, from 20 to 40 times the bankfull width. Idaho protocols for monitoring riparian vegetation (Cowley, 1992) recommend a minimum of 20 times the bankfull width or a minimum of 360 feet, using ten channel cross sections. Ten cross sections may be adequate to detect change in channel parameters.

Once sampling is initiated, the investigator may need to evaluate whether the data are sufficient to determine statistical significance. The five interacting factors assessed are sample size, variability, level of significance, power, and minimum detectable effect (MacDonald et al., 1991).

If more data are needed to detect change, additional transects may be added upstream at the same spacing or at intervals between transects. For some parameters, the number of samples for statistical tests may be increased by increasing the intensity of sampling on existing transects.

IDENTIFY REFERENCE AREAS

Site-specific reference areas are selected to be comparable to the project monitoring sites and to represent minimally disturbed conditions. Regional reference sites are selected using two primary criteria. These criteria are also useful in considering site-specific reference areas (Hayslip, ed. 1992).

Least or minimal impact: Sites that are not disturbed by human activities are ideal as reference sites. Human activity has altered much of the landscape, so truly undisturbed sites are available only rarely. Therefore, a criteria of least or minimal impact should guide selections from a suite of candidate reference sites.

Representativeness: Reference sites must be representative of the waterbodies under consideration.

Variables used to classify the monitoring site can be used to measure the representativeness of the reference site. Reference sites should be comparable by general classification criteria, including soils/geology, stream morphology, and riparian vegetation. Specific criteria include:

- Valley bottom type
- Stream size class
- Gradient
- Sinuosity
- Channel width/depth ratio
- Channel particle size class
- Channel entrenchment
- Riparian community type
- Dominant soil family

Reference sites should represent minimally disturbed conditions for the parameters that will be evaluated for grazing impacts. Candidates for reference sites are selected by consulting land ownership records, land use maps, and local experts about the degree of disturbance in the watershed. Riparian areas where livestock have been excluded to allow recovery should be sought. Candidate sites are examined through field reconnaissance to determine their value as reference sites. Assumptions regarding minimal disturbance and physical and biological integrity of the riparian area are evaluated. Some guidance criteria for selection of reference areas are listed in Table 3.6.

Table 3.6. Considerations for selection of reference sites (from Hayslip, 1992)

- Perennial flow.
- Similar stream size class as study site.
- Relatively unimpacted: minimal human disturbance to the watershed and stream system.
- Substrate materials representative of undisturbed stream type.

- Natural channel morphology: variety in channel width and depth, presence of pools, riffles, and runs typical of streams in the area.
- Natural hydrograph: flow patterns typical of the region.
- Stable banks: banks covered with vegetation, little evidence of bank erosion, and undercut banks stabilized by roots typical of the stream type.
- Natural color and odor.
- Relatively abundant and diverse algae, benthic macroinvertebrates, and fish assemblages.
- Land use stability: consistent land use management over time.
- Interdisciplinary team selection of reference site.

STUDY PLAN

A detailed study plan is an excellent communication device because it provides information to coworkers regarding their role in the overall project; communicates to managers and interest groups how monitoring will measure the desired outcomes; and displays the resource needs and commitments of the project (Table 3.7). The study plan can also illustrate tradeoffs between costs and information gained.

The introduction should clearly describe the project, monitoring start-up and ending dates, monitoring approach, and methods to provide feedback for mid-course corrections when needed. Background information on natural resources in the watershed and an evaluation of previous studies and preliminary investigations are described. The roles of participating agencies, project participants, and interest groups are discussed.

Goals and objectives based on the limiting factors for beneficial uses are listed. The reason for suspecting these limiting factors and the rationale of the monitoring design are discussed. Sampling design details include monitoring parameters, monitoring periods, monitoring sites, and the rationale for these decisions. Data collection methods are described in detail, including the assumptions and limitations of the methods. Resources needed to carry out the program are listed by personnel, equipment, laboratory support, and estimated budget.

Quality assurance (QA) and quality control (QC) procedures should be incorporated into each step of the monitoring program. Quality assurance objectives are described by five attributes - precision, accuracy, data completeness, data representativeness, and data comparability (EPA, 1992). Precision and accuracy are commonly understood measurement attributes. Precision can be estimated by examination of variability between replicate samples. Estimates of accuracy for field measurements are more difficult to make since the population true value is rarely known. The other three descriptors are more subjective evaluations of data quality. Completeness is defined as the percentage of measurements made that are judged to be valid. Representativeness is the degree to which data accurately represents a characteristic of a population or environmental condition. Comparability is a measure of the confidence with which one data set can be compared to another. Requirements for quality assurance project plans should be obtained from the local EPA regional office.

For each parameter category, the methods for data reduction, analysis, and interpretation are described. Data reduction refers to the office procedures needed to transcribe data from field sheets to computer or paper files. Analysis and interpretation may refer to water quality criteria, desired future condition analysis, or use of similarity indices. The report format, expected delivery dates, reviewers, and audience for the report are described. Preparing a monitoring study plan assures the investigator will do a thorough job and anticipate problems and scheduling conflicts.

Table 3.7. Study plan outline

I. Introduction and Background
- A. Project overview and purpose
- B. Review existing information
- C. Project organization, responsibility, and participating agencies

II. Goals and Objectives
- A. Issue identification; identify limiting factors
- B. Project goals (repeat for each goal)
  1. Monitoring objective
  2. Summary of monitoring technique

III. Study Approach
- A. Overall monitoring strategy; identify design and type of monitoring
- B. Sampling design
  1. Design rationale
  2. Station location description
  3. Station location maps
  4. Parameters, frequency, duration
  5. Monitoring schedule

IV. Data Collection Methods
- A. Monitoring procedures
  1. Sampling procedures (including QC checks)
  2. Calibration procedures and preventative maintenance
  3. Analytical methods (including QC checks)
  4. Provide reference to methods manuals or fully describe any modifications

B. Discuss assumptions and limitations
C. Describe quality assurance objectives
  1. Precision and accuracy
  2. Data representativeness
  3. Data comparability
  4. Data completeness
D. Data forms
E. Resource needs - personnel time, laboratory costs, equipment, etc.

V. Data Reduction and Analysis
A. Describe data documentation and reduction
B. Data analysis and basis of interpretation, e.g. use of water quality, criteria, desired condition, analysis, or similarity indices
C. Report format and schedule

CONDUCT FIRST YEAR OF MONITORING

The first year of monitoring is used to test the monitoring design and establish baseline conditions. Practical considerations, such as sample frequency, access to monitoring sites, and application of protocols, are evaluated. Sample size is evaluated to determine if differences can be detected. Data can also be used to better define project objectives, in terms of baseline condition or in comparison to reference areas. First year monitoring can be used to describe objectives quantitatively.

PLAN REVIEW AND REVISION

The study plan should be reevaluated periodically. Data should be reviewed at the end of each sampling season to evaluate the adequacy of the study plan. This evaluation provides an opportunity to determine which parameters are effective and sensitive to detecting change. Parameters that exhibit high variability may need to be deleted since their ability to detect change is limited. The study plan should specify plan review and revision to assure that this vital step is accomplished.

REASSESS ASSUMPTIONS AND OBJECTIVES AND MODIFY PLAN

Assumptions made during planning about monitoring sites, parameter utility, natural variability, grazing impacts, or other factors are evaluated using the first season of monitoring data. Precision can be evaluated and replication increased where needed or other methods adopted. Adjustments are made in the monitoring program to assure that it stays on target; parameters that have proven effective are retained and parameters that are ineffective are dropped or modified to increase their utility.

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IV. STREAM STRATIFICATION, RECONNAISSANCE, AND CLASSIFICATION

The planning procedures for developing a monitoring program were outlined in the previous chapter. Step II of the planning process – stratification and classification of stream reaches – and step III – the field reconnaissance – are necessary preliminary steps to monitoring site selection. These activities are essential for developing an understanding of the conditions, both natural and man-made, that occur in the area of concern. Subsequent planning and monitoring are based on information collected during these steps.

This chapter describes the process of stratification, reconnaissance, and classification of riparian areas. It involves three steps: initial evaluation, field reconnaissance, and monitoring site selection.

The **initial evaluation** is a compilation of existing information and stratification of the stream and its associated riparian area. The **reconnaissance** is a field inventory used to refine the basic data and gather additional data needed to classify a stream and its riparian area. It is also used to identify potential locations for the final monitoring sites. The monitoring sites which are eventually selected will provide site-specific data for evaluating the effectiveness of best management practices, trend of habitat factors, and status of beneficial uses.

All streams are not equal. Streams vary in size, velocity, geomorphology, erosion/deposition, vegetation, and other factors according to position in the landscape. A monitoring strategy requires stratifying or dividing the stream into reaches based on natural features, land use, and sampling requirements. The final monitoring site is selected within a reach that represents and reflects conditions and changes along a segment of a stream.

Factors such as geology, landform, soils, stream gradient, stream order, stream flow, land use, land ownership, and elevation are used to define the location of monitoring sites. Sites are also chosen as reference or control sites and may be used to establish objectives and evaluate results of management.

BASIC EVALUATION AND STREAM STRATIFICATION

The first data collection effort involves a compilation of existing information and stratification of the stream. It is usually done in the office using maps, aerial photos, existing data, and information from other agencies (e.g., state fish and wildlife management agencies, USDI Geological Survey, state water quality management agencies, universities, USDA Soil Conservation Service). This information provides the basis for the initial delineation of streams into reaches having similar characteristics, allowing streams and riparian areas to be classified.

Factors to be considered:

1. **Stream gradient** is determined from topographic maps by plotting elevations in relation to distance and is expressed as a percentage. Breaks along the stream are usually made at all distinct changes in gradient. Minimum gradient breaks are less than 2%, 2 to 3.9%, and 4% or more. Appendix B contains critical gradient breaks for stream typing.

2. **Stream order** changes usually provide breaks along a stream. Order change usually represents a change in the hydrologic characteristics of the stream.

3. **Sinuosity** is the ratio of the length of the stream divided by the length of the valley bottom. It is usually obtained by carefully measuring the length of the stream and the valley bottom on topographic maps. Sinuosity breaks are < 1.2, 1.2 to 1.4, and > 1.4.

4. **Soil family** and **geology** are usually closely related and may be used to further subdivide streams. Soil surveys and/or geologic maps provide this information.

5. **Valley bottom** types are defined from topographic maps, described in Appendix B, and are logical breaking points along a stream.

6. **Other features**, such as vegetation, land use, land ownership, diversions, culverts, and instream structures, as well as other observable features, may be used to define reaches. Key information on topographic maps and the forms is shown in Appendix A.

7. **Information sources** should be listed on the form shown in Appendix A.

STREAM RECONNAISSANCE AND CLASSIFICATION

The next step involves the reconnaissance, a field inventory of existing conditions. It provides information needed to delineate stream reach breaks, classify stream segments, locate final monitoring sites, and provide information to determine the present condition of the stream and riparian area. Other factors affecting water quality are also recorded.

It is critical that an interdisciplinary team, which usually includes a plant specialist, fishery biologist, hydrologist, soil scientist, and other specialists as appropriate, conducts the reconnaissance level inventory. Few individuals are expert in evaluating all components of the reconnaissance inventory and the classification.

Classification is the interpretation of data collected and includes information about the dominant soil family, stream type (Rosgen, 1993), and the existing dominant riparian community. Classification systems used by the USDA Forest Service, Bureau of Land Management, and USDA Soil Conservation Service are available. This classification procedure is based on the Integrated Riparian Evaluation Guide (USFS, 1992). The document Procedures for Ecological Site Inventory – with Special Reference to Riparian – wetland sites, prepared for the USDA Bureau of Land Management and the USDA Soil Conservation Service, is also available (BLM, 1992).

1. Review in detail the information obtained during the basic evaluation for each reach. Provide each team member a map containing the reach boundaries, important features, and other information (soil survey data, water quality data, vegetation information, stream features, diversions) that will assist with the reconnaissance inventory. Team members should have adequate copies of maps and aerial photos.

2. Determine the intensity of data collection for the stream appropriate to the resource values, public interest, and anticipated intensive monitoring sites. Three levels of effort suggested in the Integrated Riparian Evaluation Guide (USDA Forest Service, 1992) are a single ocular estimate, an estimate from a single representative segment, or an estimate from multiple segments.

Single Ocular Estimate: A single estimate is recorded for each element on the Stream Habitat data sheet for each reach. This is done by the appropriate team members walking the entire stream, keeping mental or written notes, and making average estimate for each element the end of the reach (see Appendix C. Instructions for evaluating each element are included with the sample data sheet.) (USFS, 1992).

Make notes of problems and issues of concern (i.e. severe streambank erosion, tributaries, irrigation return flows, good habitat conditions). Note the location on a map.

The single ocular estimate is the least intensive and least-costly alternative for data collection. It has the lowest replicability between observers and does not provide adequate information to understand the spatial variability of the various habitat attributes within the reach. It provides information on conditions of one reach compared to other reaches (USFS, 1992).

Representative Segment Estimate: The team walks the entire length of the reach and selects a segment that best represents the reach. Select a starting point at random and estimate stream attributes for five contiguous habitat units or one meander cycle (a meander cycle is usually 5 to 7 times the bankfull width), whichever is greater.

Data for each habitat unit are entered on to the Stream Habitat Data Sheet (Appendix C). The final monitoring site may be selected and used to describe the riparian vegetation, soil family, and stream channel type. Note the location of the final monitoring site on the map (USFS, 1992).

Note on the Field Data Sheets any problems and issues of concern (i.e., severe streambank erosion, tributaries, irrigation return flows, good habitat conditions). Note the location on a map.

This method provides limited information concerning the spacial variability of the various habitat attributes. It is assumed that the final monitoring site selected provides a good representation of the stream reach.

Multiple Segment Estimate: Five noncontiguous stream segments are sampled within a reach. Fewer stream segments may be used for short (less than 3,000 feet) stream reaches. The starting point for each sample segment is predetermined on a map or aerial photo prior to walking the length of the reach. Each sampled segment will be at least one meander cycle long or five contiguous habitat units. Habitat attributes are recorded for each habitat unit within the segment (USFS, 1992).

Note on the Field Data Sheets any problems and issues of concern (i.e., severe streambank erosion, tributaries, irrigation return flows, good habitat conditions). Note the location on a map.

3. Walk the entire length of each reach, with each team member providing the information for which they are responsible. If a reach needs to be divided as a result of information obtained on the ground, each team member must be given the information and a new reach designated. A Riparian Classification and Stream Habitat Data Sheet will be completed for each reach (see Appendix C).

4. Identify and record dominant riparian community types. Determine the appropriate riparian community using an accepted classification system (see Appendix D).

5. Use accepted soil survey procedures to determine dominant soil families along the stream. Order 2 soil surveys, which classify soils to the levels of association, usually provide sufficient detail for classification. This information is often available from the land management agency.

6. Record required information on both the Riparian Classification and Stream Habitat Field Data Sheet. Record the reach classification: reach number, dominant soil family, stream type, and dominant vegetation community.

7. Photograph stream channel, green line vegetation, channel alterations, erosion problems, or other factors contributing to the condition of the stream. Care must be taken to note the photograph location, direction, date, and other important information. The location should be plotted on the map.

8. Evaluate all of the information collected for the stream, and determine the factors limiting water quality (pollution), the sources of the pollution (streambanks, irrigation return flows, roads, mining), and the apparent cause of the pollution (livestock grazing, irrigation, road maintenance, road construction, urban runoff).

LOCATING MONITORING SITES

1. The initial evaluation and reconnaissance should provide sufficient information on which to base monitoring site selection. When selecting monitoring reaches, consider the pollutants impacting the stream, Best Management Practices (BMPs) to be implemented, potential reaction to management, major pollution sources, stream hydrologic functions, and resource values.

2. Walk the entire length of the selected reach, recording the location and length of all slow water (pools and glides) and fast water (riffles and runs). Record only pools whose width equals or exceeds about half the average stream bankfull width.

3. Determine average density of fast water and slow water habitat types by adding the total length of each habitat, and dividing each by the total stream reach length. If, for example, 200 feet of slow water are measured in a total stream distance of 1,000 feet, the density equals 200/1000, or 0.2 per foot.

4. Select a monitoring site that has a similar slow water and fast water density as the overall reach sample. The reach length should either be equal to or greater than 20 times the bankfull width of the stream or 360 feet, whichever is greater. Thus, a stream 25 feet wide would have a reach of at least 25 X 20, or 500 feet. If the bankfull width is 15 feet, 15 X 20 is 300 feet, 360 feet will be used.

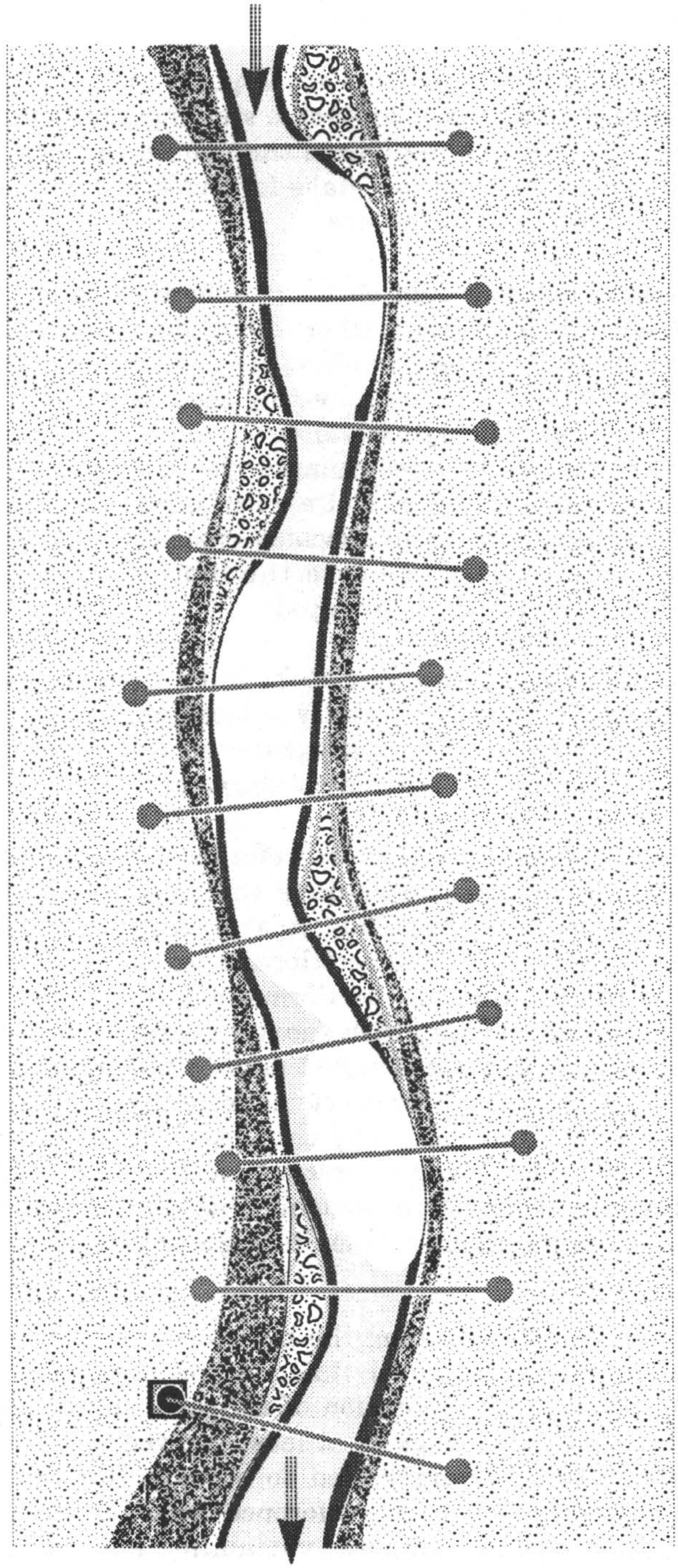

Figure 4.1 Detailed monitoring site and cross-channel transect map.

5. Place a witness marker (e.g., a steel post, marked fence post, or permanently marked tree) at the downstream starting point on the monitoring site and at a point ten feet upstream from the monitoring site marker. Then place a cross-channel transect marker stake for the study site on either side of the stream and above the high water level.

6. Place 22 transect stakes (two for each cross-channel transect) on each side of the stream equidistant from the marker to the upper end of the monitoring site. The 11 pairs of stakes should be above the high water (bankfull) level of the stream and oriented so the line connecting them is roughly perpendicular to the stream thalweg at the high water level. If a monitoring site equals 1,000 feet, for example, the 11 cross-channel transects would be at 100 foot intervals along the channel thalweg. Put a witness marker, similar to the site marker, ten feet upstream from the eleventh cross-channel transect marker and on the right side to help relocate the monitoring site should the downstream marker be removed or destroyed.

7. Mark each cross-channel transect stake with fluorescent paint, bright colored caps, and/or flagging to simplify relocation. It is also helpful to identify each transect by attaching a numbered metal tag to each cross-channel transect marker on the right side of the stream.

Record all numbered transects for future reference. If stakes are lost after initial installation, relocate and replace them by using the previously established (and recorded) spacing. Thus, it is important to record the location of the monitoring site marker, transect locations, and spacing in the field notes. Record the information on the Permanent Monitoring Site Location Data form. Provide a location map with enough information so the monitoring site may be relocated. Prepare a detailed map of the cross-channel transect location (Figure 4.1). Secondary transect markers are suggested on streams that are very unstable. Document any changes. (Note: Global Positioning System technology is a useful way to precisely locate a monitoring site. With many state and federal agencies now using this system, latitude/longitude data are important considerations for monitoring site location.)

After establishing and describing the monitoring site, monitoring involves collecting baseline and trend data over time. According to Coffey et al. (1991), baseline monitoring before implementation of nonpoint source controls is usually required to show causality. They suggest at least two years of pre-implementation monitoring of parameters strongly tied to stream flow, such as chemical constituents, to calibrate the site to the reference condition. Less time is needed with parameters that integrate temporal variability, such as physical habitat, macroinvertebrates, and fish.

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USDI Bureau of Land Management. 1992. Procedures for ecological site inventory – with special reference to riparian – wetland sites. BLM Technical Reference TR 1737-7.

V. EVALUATION/RECOMMENDATION OF MONITORING METHODS

Methods for monitoring the effects of grazing come from many disciplines: water quality, hydrology, botany, fisheries biology, range science, and others. Each of these disciplines has a set of measurement tools which are used within that specialty. In evaluating a grazing management project, the investigator may choose to use the monitoring tools of any of these disciplines.

The monitoring methods included in this report are intended for use by professionals involved in watershed restoration and evaluation projects. These professionals include water quality specialists, soil conservationists, range scientists, hydrologists, biologists, and other specialists with state and federal agencies. Many agencies have their own procedure manuals and technical guides for stream and riparian measurements which incorporate these methods or some variation of these methods.

In determining which monitoring methods to include in this report, we evaluated only those methods that are commonly used to assess the major impacts of grazing on water quality and beneficial uses. Uplands are critical to the overall health of the riparian corridor and water quality. Methods are available to measure the impact of grazing in these areas and have not been included in this document. (A companion document for monitoring uplands is being prepared under contract to EPA.)

The different methods were evaluated on the basis of their practical application to a monitoring program. The selection criteria included sampling frequency, collection time, equipment, lab costs, and expertise. Each of the selection criteria is discussed below. This discussion is followed by tables which include ecosystem attributes, methods of measuring change in these attributes, and an evaluation of each method against the stated criteria. The recommended protocols are then described, along with their advantages and disadvantages. A detailed discussion of each protocol follows this section.

EVALUATION OF METHODS

The most commonly used monitoring procedures are evaluated on the basis of their practical application to a monitoring program. Monitoring methods commonly used for evaluating the impacts of grazing on water quality are listed in Tables 5.1 and 5.2, organized by stream/riparian attribute, parameter, and protocol. An attribute is a general stream or upland characteristic that may be measured in several ways. The parameter is the physical variable that is measured and the protocol is the specific procedure for measuring the parameter. For example, vegetative shade is a stream attribute and is evaluated by canopy density and thermal input parameters. Canopy density is measured using a protocol described in Platts et al., (1987).

Table 5.1 provides information for each protocol on sample frequency, time needed for sample collection, equipment required, cost of laboratory analysis, and expertise required. A discussion of each of these categories follows.

Sample frequency: Sample collection frequency depends on the expected variation of the parameter over time. Parameters that fluctuate daily or seasonally must be sampled frequently in order to determine the mean and range. Temperature, for example, exhibits daily and seasonal cycles and can only be measured accurately by installing a continuous recorder. Suspended and bedload sediment are difficult to sample since they must be measured during high flow, either from spring runoff or a storm event. These events cannot be incorporated into a monitoring schedule. In addition, access to sites during these events is often limited.

Most water column parameters, such as sediment and nutrients, are measured as concentrations. These parameters are flow dependent since they increase or decrease with changes in runoff. Sampling these water quality parameters requires a large number of samples to define the mean and range. Small flashy streams, typical of rangeland watersheds, are very difficult to sample unless continuous samplers are used.

Stream channel and stream bank attributes are typically described by one measurement during summer base flows. The stream channel has been shaped by streamside and watershed management and the effects of high stream flows. Biological evaluations are also typically carried out during the summer low flow period. To fully describe fish and macroinvertebrate populations, seasonal sampling is recommended.

Table 5.1 lists a typical minimum sample frequency to provide a general comparison among parameters. Monitoring frequency is a major contributor to the cost of a monitoring program. Water chemistry monitoring, which requires frequent samples, increases personnel and laboratory costs. By contrast, monitoring riparian attributes during the summer low flow period requires a concentrated effort for a short duration and therefore is less expensive overall.

Collection time: Table 5.1 lists the estimated time for an experienced sampler to collect samples. These estimates do not include travel time to the site. When the method calls for a cross-section transect, the time estimate is based on ten transects per site.

Equipment needed: Only the primary equipment needed to conduct the procedure are listed in the table. Most riparian parameter measurements require only a measuring tape, survey rod, and level. It is assumed that nutrient and bacteria samples will be processed by an EPA certified laboratory, so laboratory equipment is not included.

Laboratory costs: Estimated laboratory costs are shown on a per sample basis. Most habitat parameter analysis is completed in the field so no laboratory costs are incurred for these methods.

Expertise: The expertise needed to perform a procedure is an important consideration in planning a monitoring program. This is not a limiting factor since most monitoring techniques can be readily learned. A riparian evaluation is best carried out by an interdisciplinary team that includes several disciplines: fisheries biology, hydrology, botany, geology, soils, and range management.

Expertise is listed for both field and data analysis. The primary disciplines needed for data analysis and interpretation are listed in the tables. Not all listed experts are needed, but an individual should acquire some background in the listed discipline to perform the procedure. For example, water quality specialists often learn the hydrologic techniques associated with channel classification and sediment particle size analysis.

Precision and accuracy: Precision denotes the degree of agreement between repeated measurements collected under the same conditions. For water chemistry parameters, precision can be estimated by calculating the relative range or standard deviation of replicate samples. A measurement with a small variance has high precision. For field measurements, precision is a measure of the ability of an observer to repeatedly produce the same answer. A method has high precision and reproducibility when the potential for observer error is low. Methods which include subjective ratings or observer decisions have the potential for low precision.

Accuracy is the degree of agreement between the measured value and the true value. For water quality samples, accuracy can be estimated by measuring the recovery of spiked samples. Spiked samples are samples which contain a known concentration. Accuracy is determined by comparing the results of the laboratory analysis of this sample with the known concentration. For field measurements, the true population value is not known; therefore it is not possible to routinely estimate accuracy.

Precision and accuracy were rated for several riparian variables in Platts et al. (1983). Precision was rated by evaluating the confidence intervals. A confidence interval less than 5% rated excellent, 5 to 10% rated good, 11 to 20% rated fair, and over 21% rated poor. Accuracy was subjectively evaluated from excellent to poor by comparison to yearly time trends.

The ratings in the table are derived from Platts et al. (1983) or by subjectively comparing the protocols to the methods described in that document. Standard Methods provides precision and bias estimates for most water column parameters (APHA, 1992). Bias is the reciprocal of accuracy; bias measures the average departure of estimates from the true value.

Natural variability: Natural variability is another major component of variance to consider when designing a monitoring program. If natural variability exceeds the expected improvement in a stream attribute due to the project, then the improvement will not be detected. Table 5.2 provides a rating of both spatial and temporal variability. Variability over time refers both to seasonal and yearly variation. Variability over space is evaluated by a stream reach scale.

Preferred flow/site condition: For most stream/riparian attributes the target period for monitoring is the summer low flow period when access is not a problem. However, water column parameters often need to be sampled at all stages of the hydrograph. In the case of high flows, access to streams and availability of stream crossings for sample collection is often limiting. Table 5.2 lists the usual field conditions or stream stage at which monitoring is conducted.

Complexity (Ease Rating): The complexity of the procedure influences the likelihood of its use in monitoring programs. Procedures which are less complex will be more broadly accepted by field staff. Results based on complex procedures, which are difficult to explain and describe, may not be used by managers and decision makers. The rating in the table incorporates these considerations and the need for specialized expertise. For example, the Green Line Procedure is rated a "3" since it requires a knowledge of community types and plant identification.

The primary references which provide a description of the protocols evaluated in Tables 5.1 and 5.2 are listed below. For more information about protocols not recommended in this report, please refer to these documents.

APHA (American Public Health Association). 1992. Standard methods for the examination of water and wastewater, 18th ed., American Public Health Association, Washington, D.C. **A comprehensive reference for physical, chemical, microbiological, and biological methods.**

Bonham, C.D. 1989. Measurements for terrestrial vegetation. John Wiley and Sons, New York. **This book describes measurements of vegetation, such as herbage and browse utilization, applicable to streamside vegetation.**

Cook, C.W. and J. Stubbendieck. 1986. Range Research; Basic Principles and Techniques. Society for Range Management. Denver, CO. 317 p. **A comprehensive reference for vegetative measurements.**

Plafkin, J.L. et al. 1989. Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish. U.S. EPA, Office of Water, EPA/444/4-89-001. **This document describes the rapid bioassessment protocol (RPB) procedures used as a basic tool by most states. Individual state water quality agencies should be consulted regarding state or regional modifications to these methods. Protocol I and II are qualitative macroinvertebrate**

methods applicable to reconnaissance surveys. Protocol III, for macroinvertebrates, and Protocol V, for fish communities, are semi-quantitative procedures appropriate for project assessment. Protocol IV is a questionaire approach for obtaining information on the fisheries community.

Platts, W.S., W.F. Megahan, and G.W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. Gen. Tech. Rpt. INT-138. USDA Forest Service, Ogden, UT. 70 p. **This methods manual was revised and expanded by the 1987 document listed below, but also contains some unique material.**

Platts, W.S., C. Armour, G.D. Booth, M. Bryant, J.L. Bufford, P. Cuplin, S. Jensen, G.W. Lienkaemper, G.W. Minshall, S.B. Monson, R.L. Nelson, J.R. Sedell, J.S. Tuhy. 1987. Methods for evaluating riparian habitats with applications to management. Gen. Tech. Rpt. INT-221. USDA Forest Service, Ogden, UT. 177 p. **This is a primary reference document that contains descriptions of several methods for vegetation, classification, riparian soils classification, water column measurements, streambanks, benthic invertebrates, and riparian planting guides.**

Skille, J. and J. King. 1989. Proposed cobble embeddedness sampling procedure. Unpublished paper available from the USDA Forest Service, Intermount. Res. Sta. Boise, ID., 11 p. **There are many qualitative and quantitative methods in use to estimate cobble embeddedness.**

USDA Forest Service. 1992. Integrated riparian evaluation guide. USDA Forest Service, Intermount. Region, Ogden, UT. 61 p. **This guide describes three intensity levels of riparian evaluation and brief description of several monitoring methods.**

Wolman, M.G. 1954. A method of sampling coarse river-bed material. Trans. Am. Geophys. Union 35(6): 951-956. **This reference descibes a commonly used procedure for measuring stream substrate material, and is referred to as "Wolman pebble count".**

Table 5.1. Riparian Monitoring: Minimum sample frequency, estimated collection time, equipment needed, lab costs, and expertise.

ATTRIBUTE	PARAMETER/ PROTOCOL	FREQUENCY (times/year)	COLLECTION TIME (hours/site)	EQUIPMENT	LAB COSTS ($/sample)	EXPERTISE Field/ Data Analysis
I. WATER COLUMN a. Temperature	Min/Max Thermometers	6-10 during summer	< 1	Min/Max Thermometers	None	F: Technician A: Fisheries/ Hydrology
	Recording Thermograph	Continous during summer	1 - 2	Recording Thermograph	None	F: Technician A: Fisheries/ Hydrology
b. Shade	Canopy Density/ Densiometer Platts et al. (1987)	1	2 - 4	Densiometer	None	F: Technician A: Fisheries/ Hydrology
	Solar Heat Input/ Solar Pathfinder Platts et al. (1987)	1	4 - 8	Solar Pathfinder	None	F: Technician A: Fisheries/ Hydrology
c. Nutrients	T. Phosphorus, T Nitrates Standard Methods APHA (1990)	(Twice/mo. or stream flow dependent)	< 1	Grab samples or automatic samplers	$30 - $50 per sample	F: Technician A: Fisheries/ Hydrology
d. Fecal Bacteria	Fecal Coliform, Fecal Strep. Standard Methods APHA (1990)	(Twice/mo. or more depends on objective)	< 1	Grab samples	$10 - $20 per sample	F: Technician A: Water Quality
II. STREAM CHANNEL/ STREAMBANK a. Channel Morphology	Channel Cross Section Rod and Level or Sag Tape Methods Platts et al. (1987)	1	4 - 8	Rod and level	None	F: Technician A: Hydrology
	Width/Depth ratio Platts (1983) - 3 point method	1	2 - 4	Tape and rod	None	F: Technician A: Technician
b. Streambank Stability	Streambank Soil Alteration and Stability Rating (at transect) Platts et al. (1987)	1	1 - 2	Tape	None	F: Technician A: Fisheries/ Hydrology

Table 5.1. Page 2

ATTRIBUTE	PARAMETER/ PROTOCOL	FREQUENCY (times/year)	COLLECTION TIME (hours/site)	EQUIPMENT	LAB COSTS ($/sample)	EXPERTISE Field/ Data Analysis
	Streambank Cover and Stability Rating (bank length) USDA-FS (1992)	1	1 - 2	Tape or rod	None	F: Technician A: Hydrology/ Fisheries
c. Substrate Sedimentation	Particle Size Distribution- Percent Fines Pebble Count (Wolman, 1954)	1	1	Rulers	None	F: Technician A: Hydrology/ Fisheries
	Percent Surface Fines Grid Method (See Section 6)	1	2 - 4	Metal or plexiglass grid	None	F: Technician A: Hydrology/ Fisheries
	Cobble Embeddedness Skille and King (1989)	1	4 - 8	Hoop and scale	None	F: Technician A: Hydrology/ Fisheries
d. Pool Quality	Pool Quality Rating Platts et al. (1983, 1987)	1	< 1	Measuring rod	None	F: Fisheries A: Fisheries
	Pool Quality Rating USDA-FS (1992)	1	< 1	Measuring rod	None	F: Fisheries A: Fisheries
e. Vegetative Overhang	Vegetative Overhang (at transect) Platts et al. (1987)	1	< 1	Measuring rod	None	F: Technician A: Hydrology/ Fisheries
	Vegetative Overhang (bank length) USDA-FS (1992)	1	< 1	Measuring rod tape	None	F: Technician A: Hydrology/ Fisheries
f. Streambank Undercut	Streambank Undercut (at transect) Platts et al. (1987)	1	< 1	Measuring rod	None	F: Technician A: Hydrology/ Fisheries
	Streambank Undercut (bank length) USDA-FS (1992)	1	< 1	Measuring rod tape	None	F: Technician A: Hydrology/ Fisheries

Table 5.1. Page 3

ATTRIBUTE	PARAMETER/ PROTOCOL	FREQUENCY (times/year)	COLLECTION TIME (hours/site)	EQUIPMENT	LAB COSTS ($/sample)	EXPERTISE Field/ Data Analysis
III. STREAMBANK VEGETATION a. Vegetative Composition	Green Line Survey USDA-FS (1992)	1	1 - 2	Measuring tape	None	F: Botany A: Botany/ Fisheries
b. Woody Species Regeneration	Woody Species Regeneration USDA-FS (1992)	1	1 - 4	Measuring tape and 2 meter rod	None	F:Technician A:Botany/Range Fisheries
c. Vegetative Utilization	Herbage Stubble Height transect Cook & Stubbendieck (1986)	1-3 depending on objective	1	Pacing or measuring tape	None	F:Botany/Range A:Botany/Range
	Herbage Biomass Utilization Cage method Cook & Stubbendieck (1986)	1-3 depending on objective	1 - 2	Cage, hoop, clippers, weighing scales	None	F:Technician A:Botany/Range
	Woody Species Utilization Twig count Cook & Stubbendieck (1986)	1	< 1	2 meter rod	None	F:Technician A:Botany/Range
IV. BIOLOGICAL EVALUATION a. Macroinvertebrate	Macroinvertebrate Community EPA (1989) protocol III	1 (or seasonal)	1 - 3	Sampler, sieve, alcohol	$50 - $75 per sample	F:Technician A:Entomology
b. Fish Communities	Fish Communities EPA (1989) protocol V	1 (or seasonal)	1 - 5	Electrofishing unit, nets, weighing scales	None	F: Fisheries A: Fisheries

Table 5.2. Riparian Monitoring: Estimate of precision, accuracy, natural variability, sampling conditions, and complexity

ATTRIBUTE	PARAMETER/ PROTOCOL	PRECISION/ ACCURACY	NATURAL VARIABILITY	PREFERRED FLOW/SITE CONDITION	COMMENTS	COMPLEXITY (EASE RATING)
I. WATER COLUMN a. Temperature	Min/Max Thermometers	P: Good A: Fair	Space: Low Time: High	Low flow	Good for initial evaluation.	1
	Recording Thermograph	P: Excellent A: Excellent	Space: Low Time: High	Low flow	Provides a complete data record.	1
b. Shade	Canopy Density/ Densiometer Platts et al. (1987)	P: Good A: Good	Space: Low-Med Time: High	Low flow	Applies to streams with woodsy vegetation.	2
	Solar Heat Input/ Solar Pathfinder Platts et al. (1987)	P: Good A: Good	Space: Low-Med Time: High	Low flow	Limited to small and medium streams.	3
c. Nutrients	T. Phosphorus, T. Nitrates Standard Methods APHA (1990)	P: Good A: Good	Space: Low Time: High	Depending on objecive. High and low flow.	Flow dependent - requires frequent samples to adequately sample the mean.	2
d. Fecal Bacteria	Fecal Coliform, Fecal Strep. Standard Methods APHA (1990)	P: Good A: Good	Space: Medium Time: High	Low - high flow	Flow dependent when associated w/ bottom sediments.	2
II. STREAM CHANNEL/ STREAMBANK a. Channel Morphology	Channel Cross Section Rod and Level or Sag Tape Method Platts et al. (1987)	P: Excellent A: Good	Space: High Time: Low	Low flow	Bankfull level may be difficult to locate. Usually requires a computer program for analysis.	3
	Width/Depth ratio Platts (1983) - 3 point method	P: Good A: Good	Space: High Time: High	Low flow	Water width and depth vary within season.	1
b. Streambank Stability	Streambank Soil Alteration and Stability Rating (at transect) Platts et al. (1987)	P: Fair - Good A: Poor - Fair	Space: High Time: Low	Low flow	Soil alteration is false, broken down, or eroding bank. Bank stability rates bank protective cover.	2

Table 5.2. Page 2

ATTRIBUTE	PARAMETER/ PROTOCOL	PRECISION/ ACCURACY	NATURAL VARIABILITY	PREFERRED FLOW/SITE CONDITION	COMMENTS	COMPLEXITY (EASE RATING)
	Streambank Cover and Stability Rating (bank length) USDA-FS (1992)	P: Good A: Unknown	Space: High Time: Low	Low flows	Uses simplified rating of cover and stability.	2
c. Substrate Sedimentation	Particle Size Distribution - Percent Fines Pebble Count Wolman (1954)	P: Good A: Unknown	Space: High Time: High	Low flows	Estimates percent of substrate surface area covered by fines.	2
	Percent Surface Fines Grid Method (See Section 6)	P: Good A: Unknown	Space: High Time: High	Low flows	Requires numerous plots to assess spatial variability.	2
	Cobble Embeddednes Skille & King (1989)	P: Good A: Unknown	Space: High Time: High	Low flows	Use is limiterd by high variability.	3
d. Pool Quality	Pool Quality Rating Platts et al. (1983, 1987)	P: Good A: Unknown	Space: High Time: Low	Low - moderate flows	Rates pool quality according to depth and cover.	3
	Pool Quality Rating USDA-FS (1992)	P: Good A: Unknown	Space: High Time: Low	Low - moderate flows	Rates pool quality on depth, substrate, and cover	1
e. Vegetative Overhang	Vegetative Overhang (at transect) Platts et al. (1987)	P: Fair A: Fair	Space: High Time: Low	Low flows	Measures length of overhang at each point transect.	1
	Vegetative Overhang (bank length) USDA-FS (1992)	P: Good A: Good	Space: High Time: Low	Low flows	Measures length of overhang at each point transect.	1
f. Streambank Undercut	Streambank Undercut (at transect) Platts it al. (1987)	P: Fair A: Fair	Space: Medium Time: Low	Low flows	Measures depth of undercut at each point transect.	1

Table 5.2. Page 3

ATTRIBUTE	PARAMETER/ PROTOCOL	PRECISION/ ACCURACY	NATURAL VARIABILITY	PREFERRED FLOW/SITE CONDITION	COMMENTS	COMPLEXITY (EASE RATING)
	Streambank Undercut (bank length) USDA-FS (1992)	P: Good A: Good	Space: Medium Time: Low	Low flows	Measures length of bank with undercuts.	1
III. STREAMBANK VEGETATION a. Vegetation Composition	Green Line Survey USDA-FS (1992)	P: Good A: Good	Space: High Time: Low	Low flows	Measures length of vegetation community types.	3
b. Woody Species Regeneration	Woody Species Regeneration USDA-FS (1992)	P: Good A: Good	Space: High Time: Low	Low flows	Measures number of woody plants by age class.	2
c. Vegetation Utilization	Herbage Stubble Height transect Cook & Stubbendieck (1986)	P: Good A: Good	Space: High Time: Medium	Grazing season access	Measured on top of bank after grazing & plant growth	2
	Herbage Biomass Utilization Cage Method Cook & Stubbendieck (1986)	P: Fair A: Good	Space: High Time: Low	Grazing season access	Compares grazed plot to ungrazed plot.	2
	Woody Species Utilization Twig count Cook & Stubbendieck (1986)	P: Fair A: Fair	Space: High Time: Medium	After grazing	Measures percent of twigs browsed.	2
IV. BIOLOGICAL EVALUATION a. Macroinvertebrate	Macroinvertebrate Community Plafkin, J.L. et al (1989) Protocol III	P: Good A: Good	Space: Medium Time: Medium	Low flows	RBP protocols are being locally refined by States.	3
b. Fish Community	Fish Communities Plafkin, J.L. et al (1989) Protocol V	P: Fair-Good A: Fair-Good	Space: Medium Time: Medium	Low flows	RBP protocols are being locally refined by States.	2

RECOMMENDED PROTOCOLS

A subset of the parameters evaluated in Tables 5.1 and 5.2 is recommended for evaluation of water quality improvement projects. These parameters and protocols are listed in Table 5.3 and are recommended because precise/accurate data can be obtained within the practical constraints of monitoring. The advantages and disadvantages of these methods are also described in Table 5.3.

The protocols are described in detail in Section 6 and were selected with the following criteria in mind:

- Minimum sample frequency
- Minimum specialized equipment
- Minimum lab costs
- Reduced personnel time
- Sample during accessible periods
- Methods are easily used and taught

Most stream channel, streambank, and streamside vegetation parameters are sampled only once per year and this provides adequate data for project evaluation. This reduction in personnel costs and travel time is a significant advantage over traditional water quality monitoring. Access is good during summer base flow, which is the target sample period for most of these parameters.

Many of these methods require only a measuring tape and rod, so equipment costs are relatively low. Other specialized equipment, such as the densiometer or solar pathfinder, are relatively inexpensive compared to meters used for water quality monitoring. Inexpensive recording thermographs are now available and are a convenient way to evaluate temperature.

The knowledge and skills needed to complete the protocols vary considerably by procedure. The monitoring program is best completed by an interdisciplinary team with a mix of expertise. However, many of the methods can be readily learned.

Much of the data analysis for riparian monitoring is completed in the field, which reduces data analysis costs. Nutrient and bacterial samples require laboratory analysis, but the cost per sample for these analyses is relatively low. Macroinvertebrate analyses may require laboratory processing depending on the available expertise and the protocol used.

Table 5.3. Advantages and disadvantages of selected riparian monitoring methods

ATTRIBUTE	PARAMETER/ PROTOCOL	ADVANTAGES	DISADVANTAGES
STREAM TEMPERATURE AND SHADE 1. Maximum water temperature	Min/Max Thermometers	Data for maximum temperature collected at low flows. Low equipment cost. High precision. Quick and easy method for problem identification. No special expertise needed.	Requires repeated trips to the site compared to a recording thermogaph. Less accurate than thermographs for year to year comparisons. Does not detect changes due to high temporal variability.
	Recording Thermographs	New models can be set to record for entire summer. Requires only two trips for installation and pick up. Excellent precision and Accuracy. Can be installed by technicians.	Equipment costs for thermographs has historically been high. (Some new models are inexpensive.)
Shade	2. Vegetative Canopy Density/Densiometer Platts it. al (1987)	Samples are collected at low flow stage. Frequency: once/year. Low equipment cost. Good precision and accuracy.	Collection time: Moderate. Limited to streams with woody vegetation. Measures canopyt, not thermal input..
	3. Thermal input/ Solar Pathfinder™ Platts et al. (1987)	Data can be collected during any month to estimate thermal units for the entire critical period. Frequency: once/year. Low equipment cost. Good precision and accuracy. Measures shade and thermal input directly. Data are directly applicable to temperature models.	Collection time: Moderate. Use of the solar pathfinder is not readily understood. Thermal units are not as simple as temperature and shade to explain.
NUTRIENTS	1. Total Phosphorus 2. Total Nitrates + Nitrates Standard Methods APHA (1990)	Familiar water quality attribute of concern for eutrophication.	Flow dependent attribute which requires frequent samples to estimate the mean. May be difficult to relate to identify sources. Collection time: Moderate High temporal variability. Requires lab analysis: $30 - $50 per sample.

Table 5.3. Page 2

ATTRIBUTE	PARAMETER/ PROTOCOL	ADVANTAGES	DISADVANTAGES
BACTERIAL INDICATORS	1. Fecal Coliform 2. Fecal Streptococcus 3. Coliform/Strep. Ratios Standard Methods APHA (1990)	No special field equipment needed. Water quality criteria have been adopted by states for data analysis. Samples are collected at low flows to evaluate criteria for swimming and wading.	Requires frequent samples to estimate the mean. Sample frequency increases collection time. High temporal variability. Low - Med. precision. Requires lab analysis: $10 - $20 per sample.
STREAM CHANNEL MORPHOLOGY	1. Water/channel depth 2. Water/channel width 3. Width to depth ratios Leveled Tape and Rod Protocol described in Section 6.	Channel cross sections are evaluated at low flows. Frequency: once/year. Collection time is low for leveled tape and rod method. Simple graphical analysis does not require computer software. Equipment costs: Low. Good precision and accuracy. Low temporal variability.	Bankfull level may be difficult to identify. Leveled tape and rod method may be less precise than rod and level or sag-tape methods.
STREAMBANK STABILITY MEASURES	1. Streambank stability 2. Streambank cover 3. Undercut streambank 4. Overhanging vegetation 5. Streambank Livestock utilization Protocol described in Section 6.	Data can be collected at low flows. Frequency: once/year. Collection time: Low. Low equipment cost. Simple rating systems are easy to use. Modifications of previous rating methods decrease observer error and increases precision.	Bank condition ratings are based on ocular evaluations and are therefore subject to observer bias.
SUBSTRATE FINE SEDIMENT	1. Substrate average particle size - D50 Pebble Count (Wolman, 1954)	Data is collected at low flow. Frequency: once/year. Collection time: Low. No special equipment needed and easy to use. Good precision. Pebble counts provide a simple method for evaluating surface fines given high spatial variability.	Surface fines have high natural temporal variability.
	2. Percent substrate fine sediment Grid Method described in Section 6.	Data is collected at low flow. Frequency: once/year. Low equipment cost. High precision. Allows assessment of microhabitats - useful for macroinvertebrate and embeddedness assessments.	Surface fines have high natural temporal variability. Collection time is higher for the grid method than for pebble counts, but, less than cobble embeddedness methods.

Table 5.3. Page 3

ATTRIBUTE	PARAMETER/ PROTOCOL	ADVANTAGES	DISADVANTAGES
POOL QUALITY	1. Pool quality rating 2. Pool condition USDA-FS (1992)	Data collected at low flow. Frequency: once/year. Collection time: Low. Low equipment cost. Modification of previous rating methods to include substrate in the rating system. Easy to describe to users.	Subjective rating system requires fishery expertise.
STREAMSIDE VEGETATION	1. Vegetative composition (greenline survey) USDA-FS (1992)	Frequency: once/year. Collection time: Low - Med. No specialized equipment. A sensitive indicator of adverse livestock grazing impacts on streams.	Requires professional skills to identify plants and community types. Complex to describe to users.
	2. Woody Species Regeneration (age class) USDA-FS (1992)	Frequency: once/year. No specialized equipment.. A sensitive indicator of recovery following management change.	Collection time: moderate to high. Location of measurement may shift over time as recovery occurs.
	3. Vegetative utilization (stubble height) Transect method described in Section 6. After Cook & Stubbendieck (1986)	Frequency: once/year after grazing season. (More frequently for management purposes.) No specialized quipment. Easy to measure.	Requires botany/range skills to identify plants. High spatial variability.
BIOLOGICAL EVALUATION	1. Macroinvertebrate Community Protocol III Plafkin, J.L. et al. (1989)	Data is collected at low flow. Frequency: 1 - 3 times a year. An indicator of the biological integrity of the stream. Integrates impacts over time. Note: Protocol I & II are qualitative methods and therefore not included.	Specialized equipment needed. Requires entomology skills in field; identification is used. Otherwise requires lab identification. Lab costs: $50 - $75 per sample
	2. Fish Communities Protocol V Plafkin, J.L. et al. (1989)	Data is collected at low flow. Frequency: once/year. Direct measure of the beneficial uses of the stream. Note: Protocol IV is a questionaire – not applicable to project evaluation.	Collection time: high. Equipment cost: high. Other factors such as climate and harvest influence observations. Requires professional fisheries expertise in the field.

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VI. MONITORING PROTOCOLS

A. STREAM TEMPERATURE AND SHADE

PARAMETER LIST

Parameters associated with this monitoring procedure include:

1. Maximum water temperature
2. Vegetative canopy density
3. Thermal input

OVERVIEW

The amount of sunlight entering a stream determines, to a large extent, the rate of water warming. Water temperatures vary normally each day and season of the year. Temperatures which exceed the optimum for salmonids reduce growth rates and adversely affect survival. The upper optimum temperature limit for most salmonids is 13 to 16°C (Bjornn and Reiser, 1991). Feeding rates decrease with temperatures over 16.7°C (Binns, 1979).

Temperature regimes altered by livestock grazing result from changes in the amount of thermal energy entering the stream system. Loss of riparian vegetation and increases in channel cross section length increase the water surface exposed to sunlight. Warming of the stream, especially during periods of low flow, can be large and abrupt. Even short duration high temperatures can decimate salmonids if they exceed the lethal limits which range from about 23 to 29°C. Detecting such abrupt, short periods of warming requires frequent temperature measurements throughout the warm season, usually from July through September.

Thermal input from solar radiation has been negatively correlated with salmonid biomass in the western United States (Binns 1979, Platts and Nelson 1989). The data in the latter study were derived from 17 study areas in Idaho, Nevada, and Utah. Thermal input was highly and negatively correlated to amount of streamside vegetative canopy (-.86). Influences of grazing were evaluated at these sites on range and meadow lands. The difference in canopy density and thermal input on grazed versus ungrazed sites was significant at p=.10. On average, canopy density was 60% higher and thermal input 12% lower on ungrazed streams as compared with the grazed sites. At some sites protected from livestock grazing, increased streamside canopy density could be measured over time. The rate of recovery was slow at other sites with no detectable change in 4 years.

DEFINITIONS

Vegetation canopy cover: The area of the sky over the stream channel bracketed by vegetation (Platts et al; 1987, page 58).

Vegetation canopy density: The amount of sky (or sunlight) over the stream channel blocked by vegetation (Platts et al; 1987, page 58).

Thermal input: The amount of solar energy (in BTU's/ft^2/day) striking the water surface.

DATA COLLECTION AND ANALYSIS

Temperature - data collection

Thermographs: Temperature data is collected by using waterproof recording thermographs. With the use of computer chips to record data, the cost of these units is decreasing. Data can be easily downloaded to spreadsheet software to decrease data analysis time. The recording thermographs provide a complete temperature record for year to year or station comparisons.

Min-Max thermometers: Temperature can also be evaluated using inexpensive minimum-maximum or maximum-registering thermometers. These thermometers are particularly useful for an initial evaluation of temperature problems. However frequent trips are required to collect data and fewer data points are recorded that allow statistical comparisons.

Temperature - data analysis

Temperature data are evaluated by comparison to State Water Quality Standards for cold water or warm water biota. Procedures are available to develop site-specific criteria for sensitive species (Guidance for Evaluating and Recommending Temperature Regimes to Protect Fish, Armour, 1991).

EPA Water Quality Criteria for Water (EPA, 1986) specify two upper limiting temperatures for summer based on the important sensitive species found at a location. States use these procedures to specify criteria in water quality standards.

1. **Maximum criteria.** One limit is a maximum temperature for short term exposures. This criterion is derived from laboratory tests at temperatures that result in 50% mortality. A 2°C safety factor is deducted from the Lethal Limit.

2. **Maximum weekly average temperature.** This limit is based on growth as it affects the long-term health of a population. The EPA criteria are derived from a formula using the optimum temperature for growth with a factor to

estimate the zero net growth. The factor used is one-third of the difference between the upper lethal temperature minus the optimum temperature.

These criteria are derived from applying equations to laboratory data and may not account for the magnitude of temperature variation in the natural environment. Hokanson et al. (1977) suggested more conservative criteria than EPA criteria based on their work on fluctuating temperatures; they recommend a weekly average temperature for rainbow trout of 17°C and a maximum thermal criterion of 23°C.

Table 6.1. Temperature criteria (°C) for selected species. Maximum weekly average temperatures for growth and short-term maxima for survival of juveniles and adults during the summer (EPA, 1986)

Species	Weekly Average	Maxima
Brook Trout	19	24
Coho Salmon	18	24
Northern Pike	28	30
Rainbow Trout	19	24
Sockeye Salmon	18	22

Vegetation canopy - data collection

Vegetative canopy density is estimated using a modified concave spherical densiometer as described in detail by Platts et al., (1987). The densiometer consists of a concave mirror surface with etched grid that reflects vegetation and other obstructions to sunlight over the stream surface (Figure 6.1). The grid is modified by enclosing 17 grid intersections with tape (Figure 6.2).

On stream orders 1 through 4, readings are taken at four points along the line transect: 1) at the left streambank; 2) right streambank, and from the center of the stream facing; 3) upstream and facing; 4) downstream (Figure 6.3). The sum of intersections blocked by vegetation or other obstructions is added together from the four readings and multiplied by 1.5 to estimate percent canopy density. A correction is applied for rounding error; 1% is deducted from scores between 30 and 60%, and 2 percent is deducted from scores over 66%.

For stream orders 5-7, the same procedure is used except eight readings are taken across the transect. Two additional readings, one facing upstream and one downstream, are taken at the quarter and three-quarter interval along the transect (Figure 6.3). The eight recordings are totaled and multiplied by 0.75 to obtain percent canopy density. The correction for rounding error is applied: 1%

deducted from scores between 30 and 65%, and 2% from scores over 66%. No deduction is made for scores between 0 and 29%. The user is referred to Platts et al. (1987), pages 58 through 60, for details on this technique.

Data collected using the canopy densiometer are recorded on the field data sheet shown in Table 6.2.

Figure 6.1. The concave spherical densiometer, Model C

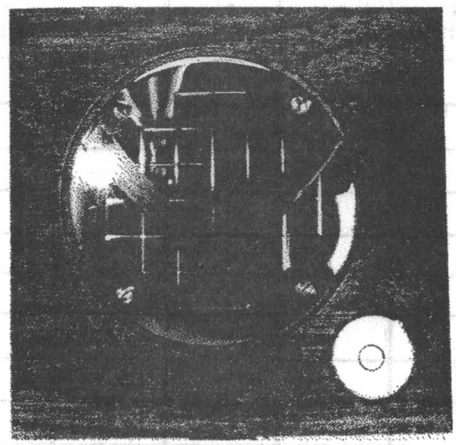


Figure 6-2. Use of spherical densiometer showing placement of head reflection and 17 points of observation (From Platts et al., 1987)

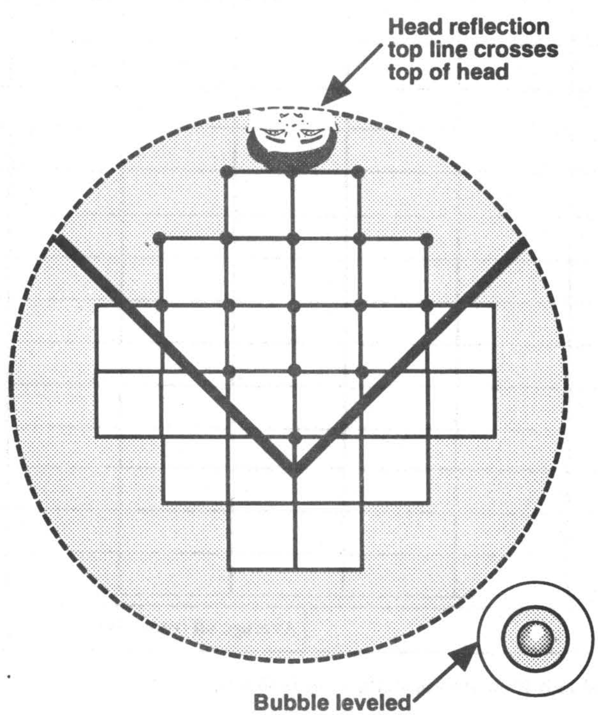


Table 6.2. Vegetative canopy density survey

STREAM NAME:______________________________ DATE:______________

INVESTIGATORS:______________________________STREAM REACH DESCRIPTION______________

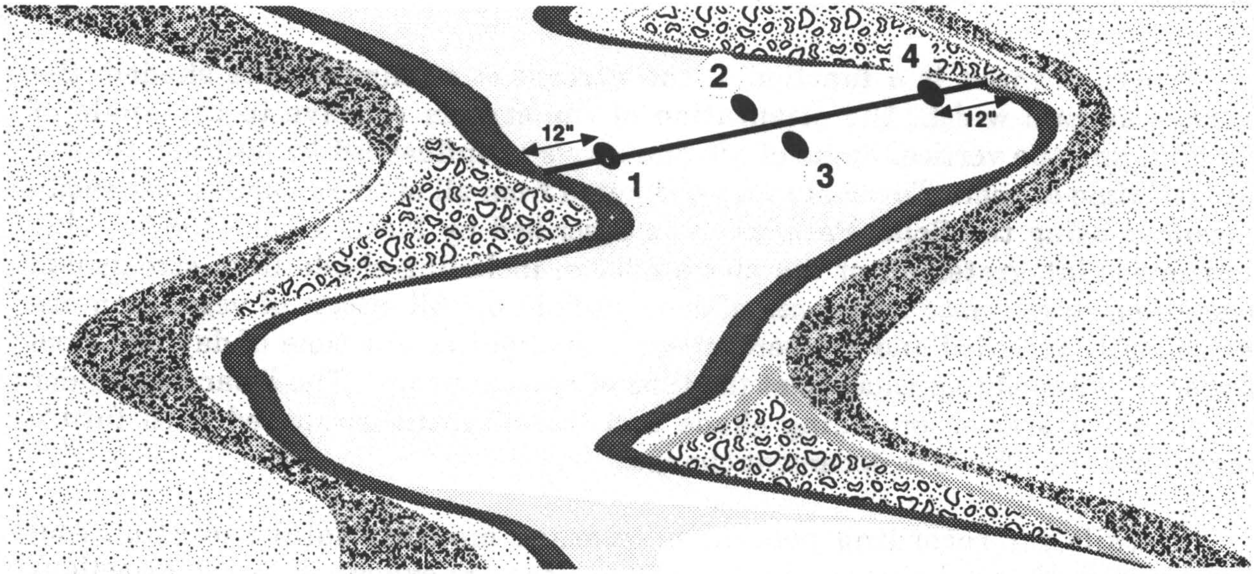
Transect number	Left Bank number (0-17)	*1/4 Dist Upstream # (0-17)	*1/4 Dist Dn.stream # (0-17)	Midstream Upstream # (0-17)	Midstream Dn.stream # (0-17)	*3/4 Dist Upstream # (0-17)	*3/4 Dist Dn.stream # (0-17)	Right Bank # (0-17)	Total for Transect #	Percent Canopy
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										

Total all transect=	Average all transects=

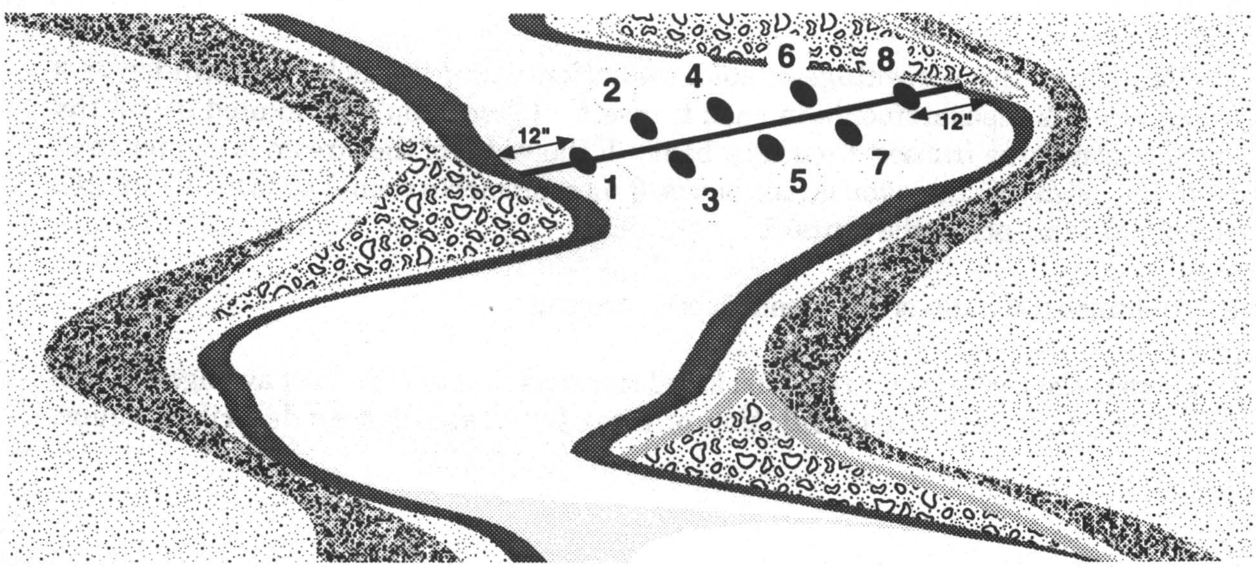
* These sites on the transect are used only if the stream width exceeds 50 feet

Figure 6.3. Location of densiometer for measuring canopy density. Four readings are used in stream orders 1-4 and eight readings in stream orders over 4.

Stream order 1 - 4



Stream order 5 - 7



Canopy density- data analysis

Use the field form in Table 6.2 to total and average percent canopy density for the measurements made on all transects. The canopy density condition can then be estimated by comparing these measurements with like measurements at ungrazed or lightly grazed reference sites. Such comparisons require that the reference site(s) be located on streams of similar order and of similar soils. The stream width is strongly influenced by these variables, as are the potential natural streamside vegetation communities.

Thermal input - data collection

Thermal input is a function of the percent of stream surface shaded, the average stream width, the orientation of the stream relative to the angle of sunlight, and the vertical angle of the sun's rays as influenced by latitude, time of day, and time of year. Thermal input estimated from all of these variables is easily measured using the Solar Pathfinder as described by Platts et al. (1987). This instrument integrates all of the above effects, including shade from streamside vegetation, to estimate influences of solar radiation. All effects of vegetation are permanently recorded and the percentage of sunlight at any time of day and time of year is obtained immediately at the time of measurement. The Solar Pathfinder records all obstacles providing shade and these can be compared with future measurement of shade to document change.

Details for recording percent of average monthly total radiation and conversion to thermal energy input to the surface are explained in the directions that accompany this instrument. The method for monitoring a specific reach of stream requires following these steps using Table 6.3.

1. Determine the percentage of solar radiation using the Solar Pathfinder at a minimum of 2 measurements in each transect. These should be located at 1/3 the distance across the transect from each bank. If the width of the stream is greater than twice the height of vegetation on the banks, 3 measurements should be made at 1/4, 1/2, and 3/4 distance across the transect.

2. Determine the width of the stream at each transect.

3. Average the percent solar radiation for all transects to obtain transect averages. These values then go into the calculation of total thermal input as described below.

Table 6.3. Thermal input using Solar Pathfinder

STREAM NAME:____________________ **DATE:**__________

INVESTIGATOR:____________________ **STREAM REACH DESCRIPTION**__________

MONTH:____________________

Transect number	Left half of transect (% solar radiation)	Right half of transect (% solar radiation)	* Center of stream (% solar radiation)	Average % solar radiation	Mean daily solar energy for the month times % solar radiation (BTUs/Ft²/day	*Stream width (Ft.)	Transect spacing (Ft.)	Total thermal input for transect interval A x B x C
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
Total all transects=								

*** This location applies only if the stream width is greater than two times the height of the streamside canopy vegetation.**

Thermal input - data analysis

The input temperature or average maximum temperature at the upstream end of the reach should be measured using average daily maximum/minimum thermometer readings, or average maximums obtained from a recording thermometer.

Use the data in Table 6.3 and the tables which accompany the Solar Pathfinder to calculate total thermal input into the stream reach during the warmest month of the year (usually mid July to mid August), and the percent of the water surface shaded during that same time period (target time period).

It is necessary to know the discharge of the stream and average water width during the target time period. Discharge can be obtained from any gaging station(s) in the study stream reach or measured as with a current meter. Water widths should be measured at all transects in the monitoring site and averaged to derive the mean water width for the segment. If the reach evaluated receives substantial volumes of inflowing water, widths and discharge may have to be made at several stations throughout the reach to obtain reasonable averages.

Calculate temperature increase for the reach using a temperature model such as SSTEMP which is explained in detail in Platts (1990, pages IV-32 to IV-47). This program receives the above described inputs and produces estimates of minimum, mean, and maximum daily water temperatures at some specified distance downstream. Because it calculates temperature changes resulting from the amount of shading and water width, it can be used to predict water temperature changes under improved riparian conditions. Such temperatures in relation to the habitat requirements for salmonids provide a very direct assessment of beneficial use support.

Data from the survey can be used to determine the total thermal energy striking the water surface as influenced by vegetation canopy and water surface exposed area. Data can then be used to estimate increase in temperature over a reach of stream. Data interpretation evaluates the extent canopy shading and channel width contribute to warming and if such warming exceeds desirable temperature ranges for salmonids. If temperatures are limiting salmonid productivity, the calculations can be used to estimate how much reduced exposure (increased shading/width reduction) is needed to obtain desired temperature regimes.

EQUIPMENT LIST

The following equipment is needed for this monitoring procedure.

1. Canopy densiometer (canopy cover/density)
2. Waders
3. Measuring tape (widths)
4. Forms - Tables 6.2 & 6.3, Pathfinder charts
5. Solar Pathfinder (thermal input)
6. Clip board

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B. NUTRIENTS

PARAMETER LIST

Recommended parameters include:

1. Total Phosphorus

2. Total Nitrite plus Nitrate

OVERVIEW

Nutrients from livestock wastes may stimulate excess algal and aquatic plant growth. During low flow periods these plant growths may contribute to nighttime oxygen depletion in streams; however, the primary concern is for eutrophication of downstream lakes and reservoirs.

The impact of grazing on nutrient enrichment is a function of livestock waste concentration and opportunity for runoff of waste into the receiving stream. Nutrient enrichment from unconfined livestock grazing in arid watersheds may be minimal (ARS, 1983). Opportunity for nutrient runoff increases with streamside pastures, but several studies have shown no significant increase in nutrient concentrations (Owens et al., 1983; Gary et al., 1983; Dixon et al., 1983). The greatest opportunity for nutrient enrichment is likely associated with runoff from stream-side confined animal feeding operations.

Phosphorus and nitrogen are the major growth-limiting nutrients. Phosphorus occurs in surface waters almost solely as phosphates. **Total phosphorus** provides a good measure of the phosphorus in the stream since it includes orthophosphate in solution as well as phosphates associated with the suspended material. **Dissolved ortho-phosphate** is considered a better measure of biologically available phosphorus since it only includes unbound phosphate forms.

Nitrogen occurs as nitrate, nitrite, ammonia, and organic nitrogen in surface waters. All these forms of nitrogen, as well as nitrogen gas (N_2), are biochemically interconvertible (APHA, 1992). Total oxidized nitrogen is the sum of nitrite and nitrate. Measuring this form, total NO_2 plus NO_3, measures most of the nitrogen available in surface waters. Ammonia and organic nitrogen are of importance only where there is a concentrated source of livestock wastes. Ammonia and organic nitrogen are measured by the Total Kjeldahl Nitrogen (TKN) procedure.

National criteria have not been set for nutrients because of the differing sensitivity of waterbodies for eutrophication. General guidance provides that total phosphates as phosphorus should not exceed 50 ug/L in any stream at the point where it enters a lake or reservoir. For streams which do not discharge directly into lakes or impoundments, a maximum of 100 ug/L is recommended (EPA, 1986). It is generally recommended that concentrations of nitrate should be less than 300 ug/L to prevent nuisance algal growths.

DEFINITIONS

Total phosphorus: Phosphorus as P determined by colorimetry after digestion of organic matter in an unfiltered sample.

Dissolved ortho-phosphate: Ortho-phosphate as P determined from a field-filtered sample; considered a measure of the biologically available phosphorus.

Total Nitrite plus Nitrate: The oxidized form of nitrogen, NO_2 plus NO_3, determined from the whole sample.

DATA COLLECTION PROCEDURE

Parameters: It is recommended that samples be routinely analyzed only for total phosphorus (TP) and total nitrite plus nitrate (NO_2 plus NO_3). Ortho-phosphate may provide the best measure of bio-available phosphorus; however, measuring this form requires field-filtration and analysis within 24 hours, since a preservative is not used. Measuring total phosphorus is sufficient for most studies and does not have these additional sampling constraints.

Total NO_2 plus NO_3 provides an adequate measure of nitrogen for most surface waters. Ammonia is usually low in comparison to nitrates. TKN measures the organic component, so this parameter fluctuates with the amount of suspended material in the sample. Ammonia and TKN should only be sampled where the effect of concentrated livestock wastes on enrichment is a key issue.

Sample collection: Samples should be representative of the entire stream flow. A depth-integrating sampler, such as the US DH-48, can be used to collect a cross-composite sample. When a depth-integrating sampler is not used, the sample should be collected at several points across the stream, e.g., at three equidistant points across the channel. Samples are collected in glass or disposable polyethylene plastic containers and are preserved for TP and nitrates by addition of sulfuric acid to pH less than two. Refer to *Standard Methods* (APHA, 1992) or the analytical lab for details of sample preservation and holding times.

Nutrient parameters are influenced by discharge and suspended solids. Samples are collected in relation to the stream discharge to calculate nutrient loading from the watershed. A large number of samples is needed to adequately represent all stages of the hydrograph. A more feasible objective is to sample nutrients only during the low summer flow periods when they are available for plant uptake. This reduces the temporal variability but misses the watershed loading period.

DATA ANALYSIS

Samples should be submitted to a certified laboratory to assure data quality. Analysis methods are described in *Standard Methods* (APHA, 1992). Commonly used methods, preservative, and suggested criteria are listed in Table 6.4 (EPA, 1979).

Table 6.4. Recommended nutrient parameters for general stream assessment

Parameter	Method of Analysis and Criteria	Preservation
T. Phosphorus as P	Persulfate digestion procedure. Suggested criteria - 100 ug/L	Sulfuric Acid
Dissolved Ortho-phosphate as P	Field filtered: Direct colorimetry. Suggested criteria - 100 ug/L	Field filtration 4°C
T. Nitrite + Nitrate as N	Cadmium reduction method. Criteria - 300 ug/L	Sulfuric Acid

Data can be analyzed by comparison to criteria suggested by EPA or as recommended by the state water quality agency for nutrient sensitive waters. Mean values can also be compared to values from reference watersheds if parallel data sets are collected.

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C. BACTERIAL INDICATORS

PARAMETER LIST

Parameters used as bacterial indicators include:

1. Fecal coliform bacteria
2. Fecal streptococcus bacteria
3. Fecal coliform/streptococcus ratio

OVERVIEW

Fecal coliform (FC) and fecal streptococcus (FS) bacteria are indicators of fecal contamination from warm-blooded animals. Fecal coliform criteria are specified in state water quality standards to assess the suitability of surface water for recreational and domestic use. For water quality studies, these bacteria also provide a method for detecting the entry of livestock wastes into surface water and are useful for general comparison between stations.

Bacterial contamination results primarily from direct deposition of fecal material into the stream or when this material reaches the stream from overland flow (Miner et al., 1992). Bacterial numbers increase when cattle are turned into a pasture and the numbers may remain high for some time after cattle are removed (Stephenson and Street, 1978; Jawson et al., 1982). Once bacteria enter the stream the majority of the bacteria settle to the bottom. The bottom sediment acts as a reservoir for fecal coliforms; bacteria are resuspended when bottom sediments are disturbed through increased turbulence or animal movement (Sherer et al., 1988). Survival time is increased when these bacteria are associated with sediment; half-lives from 11 to 30 days for FC and 9 to 17 days for FS (Sherer et al., 1992). In arid rangelands bacterial contamination may be minimal due to the limited overland runoff (Buckhouse and Gifford, 1976; ARS, 1983).

Ratios of FC/FS have been used as indicators of the relative source of bacteria in a stream (Geldreich, 1976; Baxter-Potter and Gilliland, 1988). A ratio greater than four is considered indicative of human fecal contamination, whereas a ratio of less than 0.7 suggests contamination by nonhuman sources. However, routine use of the FC/FS ratio may no longer be advisable. Variable survival rates of different species of FS have been observed leading to erratic ratios (Sherer et al., 1992; APHA, 1992), and the KF membrane filter procedure for FS has a high false-positive rate (APHA, 1992). The requirements for using the FC/FS may also be difficult to meet in routine monitoring. These requirements include: 1) contamination is recent, collected within 24 hours of stream travel time from the source; 2) FS counts greater than 100/100 ml; and 3) collected within a pH range of

4.0 to 9.0 (Tiedemann et al., 1988). The most recent edition of Standard Methods (APHA, 1992, pp. 9-70) concludes that the use of the FC/FS ratio is generally not recommended. The problem of false positives may be overcome by using more specific media for streptococcus species.

DEFINITIONS

The coliform group consists of several genera of bacteria belonging to the family Enterobacteriaceae, the bacteria being defined by the method of detection (APHA, 1992).

Total coliform: All aerobic and facultative anaerobic, gram-negative, nonspore-forming, rod-shaped bacteria that ferment lactose with gas and acid formation within 24 hours at 35°C. Includes *Escherichia coli*, *Klebsiella*, *Enterobacter*, and others.

Fecal coliform: Bacteria as defined above with the exception of using an elevated incubation temperature of 44.5°C which separates bacteria of fecal origin (primarily *E. coli*) from bacteria derived from non-fecal sources.

Fecal streptococcus: Group of species of the genus *Streptocccus*, such as *S. faecalis*, *S. faecium*, *S. avium*, *S. bovis*, *S. eqiinus*, and *S. gallinarum*. All have been isolated from the feces of warm-blooded animals.

DATA COLLECTION PROCEDURES

Samples for bacterial examination are collected in bottles that have been cleaned, rinsed, and sterilized or collected in pre-sterilized plastic bags. Samples are taken from a surface stream by holding the bottle near its base and plunging it, neck downward, below the surface. The bottle is turned into the current to collect the sample or, when there is no current, by pushing the bottle forward to create an artificial current. These precautions prevent contamination by the investigator. Samples are kept below 10°C in an ice chest during transport and should be processed within eight hours, with a maximum interval to processing of 24 hours (APHA, 1992).

Study design considerations: Populations of indicator bacteria in wildland streams fluctuate wildly in response to common environmental changes (Bohn and Buckhouse, 1985). Bacterial numbers exhibit high temporal and spatial variability. Coliforms usually increase throughout the day peaking in the evening. Coliform counts also increase dramatically in response to storm and runoff events. Fecal coliforms survive for long periods in cow feces (up to a year), so that bacterial numbers may be influenced by past activities. Bottom sediments are a significant reservoir for fecal coliforms that may be resuspended by streamflow or animal disturbance. Wildlife, including mammals and waterfowl, are a source of coliforms in addition to livestock. These factors must be taken into account when designing studies and interpreting results.

Sample collection frequency is an important consideration, given the high temporal variability. If comparison to recreational use standards is a high priority, then sample frequency needs to satisfy the minimum sample number (e.g. five samples taken over a 30 day period for calculation of means). State standards also have a single sample standard that could be used for data interpretation. However, calculation of means or trends for yearly comparison would require a high sample frequency. These samples would need to be taken only during the season specified for protection of this use; usually this is the summer period when streams are used for swimming and wading.

Where rangelands are remote from population centers, comparison to standards for recreational use may be a lower priority. A more generic purpose for bacterial samples is to assess the entry of livestock waste into a waterbody; for this purpose a less rigorous sample frequency would suffice.

DATA ANALYSIS

The standard test for coliform bacteria is carried out using the membrane filter or the multiple-tube fermentation MPN technique described in *Standard Methods* (APHA, 1992). The membrane filter technique is used most often because a large number of samples can be processed and numerical results are obtained more rapidly than with the multiple-tube procedure. The membrane filter technique is limited by waters with high suspended sediment in which case the multiple-tube technique is used. State and regional health laboratories are usually set up to run MPN tests since domestic water supplies are routinely tested for fecal coliform.

Fecal coliform bacteria are evaluated against state water quality standards for the protection of recreational uses. Most state water quality standards follow the EPA Redbook recommendations for criteria using fecal coliform bacteria (EPA, 1976). The revised EPA Water Quality Criteria (EPA, 1986) recommends use of *E. coli* and *enterococci* as public health indicators, but most states have not changed bacterial tests. Local state water quality standards should be checked to determine requirements for sample frequency and test procedures.

If characterization of bacterial source is a priority, then FC/FS ratios could be considered. However, the precautions described in Standard Methods (APHA, 1992) and other sources (Tiedemann et al., 1988; Geldreich, 1976) in collecting, analyzing, and interpreting data should be followed. In surface waters it is often difficult to satisfy the requirement of recent fecal contamination since streams integrate bacterial pollution over time. Therefore, samples routinely fall into the FC/FS ratio (0.7 to 3.0) that characterizes aging fecal pollution which is of little value.

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D. STREAM CHANNEL MORPHOLOGY

PARAMETER LIST

Parameters associated with this monitoring procedure include:

1. Water/channel depth
2. Water/channel width
3. The ratio of water/channel width to depth

OVERVIEW

Several studies have related salmonid abundance to water width, water depth, pool volume, and streamflow (Hynes, 1970; Marcus et al., 1990; Binns, 1979). These factors influence fish abundance as they affect total space for rearing. Water depth can also provide hiding cover when in excess of 1.5 feet (Wesche, 1980).

The cross section of a stream channel provides information valuable for determining total space available for fish and the annual variability of this space related to streamflow and channel morphology. Such measures for both low and bankfull flow levels in the stream provide an estimate of the annual variation in rearing space which, as reported by Binns (1979), strongly influences salmonid production.

Riparian areas overgrazed by livestock often have artificially reduced salmonid living space caused by stream channel widening (Platts & Nelson, 1989a; Platts, 1989; Lloyd, 1986). This alteration proceeds from narrow and deep channel structure in natural condition to wide and shallow channels in impaired condition. Changes in channel morphology as they affect living space for fish are best represented by a simple estimate of the average width and depth of the stream or channel, factors which also estimate the average cross sectional area of the channel.

Channel downcutting caused by riparian degradation can lower local water tables and reduce the volume of base flow available in dry seasons and periods of drought. Riparian vegetation has been linked to the water-holding capacity of streamside aquifers (Platts, 1990). As aquifers lose their capacity to hold and slowly deliver water to the stream, the difference between the high and low discharge rates increases dramatically. Thus, water width and depth estimates at low flow discharge compared with the same at high streamflow rate can be used to monitor recovery of base flow conditions in improving riparian conditions.

Streamflow is a function of stream width, depth, gradient, wetted perimeter and channel roughness (BOR, 1981). If gradient and roughness are assumed to be constant at varying discharge levels, the stream width and average depth are directly proportional to streamflow. Using this technique, low flow and bankfull stream width and depth are measured on each of the transects. The channel measures are averaged for all transects at the monitoring site. A cross section is drawn which represents the average profile for the channel and depicts the average available pool volume.

Streams with narrow, deep profiles provide more efficient conduits for streamflow so that salmonid living space is less variable between high and low discharges. Such channels usually have greater pool volume and provide greater amounts of space at low streamflow. Thus the morphology of the channel cross section determines to a large degree the amount of rearing space and quality of cover for fish.

Figure 6.4 illustrates the morphology of a stream channel with high and low streamflows of 50 cubic feet per second (CFS) and 10 CFS respectively. Example 1 is a stable, narrow, deep meandering stream channel with numerous undercut banks and considerable pool volume. Example 2 is the same channel with altered and false banks resulting from slumping. It is in degraded condition where undercut banks have been lost to bank breakdown and stream width has been increased significantly. Example 3 is the same channel further degraded where the sediments from previously slumped banks now fill pools, banks are bare, and resultant sedimentation effects have increased channel width and decreased channel depth.

DEFINITIONS

Width to depth ratio: The ratio of water width to average water depth is a good indicator of channel cross section shape. As streams become wider and shallower, this ratio increases dramatically. As shown in Figure 6.4, the width/depth ratio increases with channel degradation. Note that for deep, narrow channels as in Example 1, the ratio is lower at bankfull flow than at low flow. This reflects the effect of underbank scour which can cause a channel to widen at lower stages of flow while maintaining a narrower width at the bankfull level.

Bankfull channel: The bankfull channel contains the momentary maximum peak flow, one which occurs several days in a year and is often related to the 1.5 year recurrence interval discharge. Indicators of bankfull streamflow level are any one or combinations of the following. For well-confined stream channels, that is, stream channels where the lateral movement is restricted:

- The limit of sod forming vegetation on the margins of the channel.

- The ceiling of well-defined, overhanging streambanks.
- The upper limit of stream channel scour below which perennial vegetation does not occur.

For poorly confined, or unconfined stream channels, it is the point on the channel margin where streamflow just begins to flow onto the first terrace or floodplain.

Low flow channel: This is the channel below the water surface level during the annual period of low flow (usually late summer). The low flow level in the cross section is often the water surface at the time of sampling in mid to late summer. The flow at this time is often low enough to expose gravel/sand bars. The low flow channel is sometimes evidenced by a distinct channel impression between the inner-berm bars.

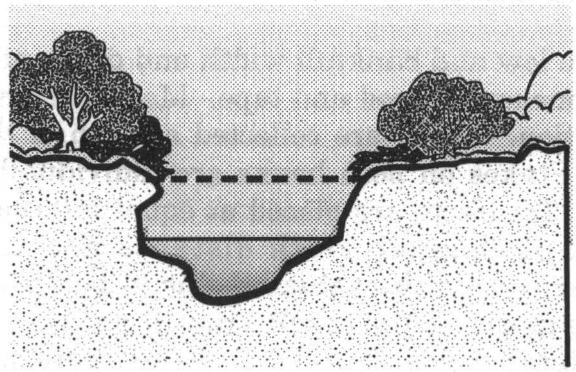
EXAMPLE 1. STABLE CHANNEL

At Bankfull discharge (50 CFS):

Width	= 5.0
Depth	= 2.5
Width/depth	= 2.0

At Low flow discharge (10 CFS):

Width	= 5.2
Depth	= 1.4
Width/depth	= 3.7



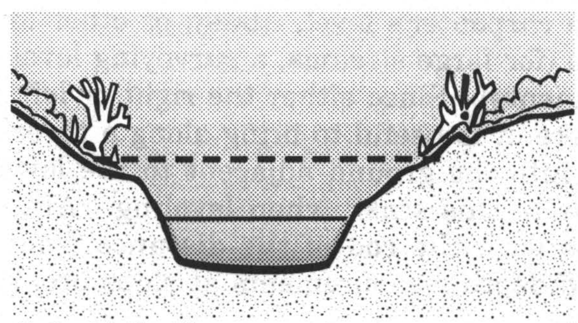
EXAMPLE 2. FALSE BANKS

At Bankfull discharge (50 CFS):

Width	=15.6
Depth	= 1.2
Width/depth	=13.0

At Low flow discharge (10 CFS):

Width	= 6.5
Depth	= 1.1
Width/depth	= 5.9



EXAMPLE 3. DEGRADED

At Bankfull discharge (50 CFS):

Width	=16.7
Depth	= 0.9
Width/depth	=18.7

At Low flow discharge (10 CFS):

Width	= 7.2
Depth	= 0.6
Width/depth	=12.2

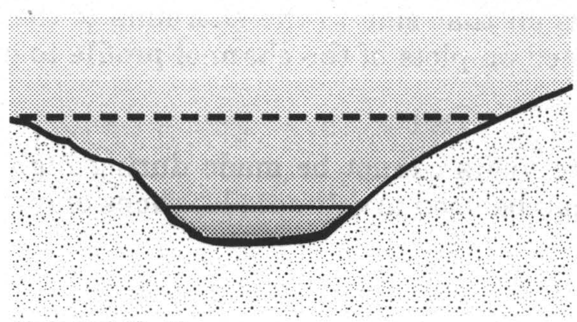


Figure 6.4. Comparison of three channel cross sections: stable banks, false banks, and degraded condition

DATA COLLECTION METHODS

The average low and bankfull width and depth of the channel are measured using a standard measuring rod and tape. Measurements are made on the stream channel cross section. Data are collected at each of the staked transects in the monitoring site. Stakes on both banks are individually marked to identify each transect number. Transects are placed at equal intervals of approximately one to two times bankfull channel width distance apart. Using this design, the monitoring site stream reach evaluated should be at least 20 times the bankfull width of the channel. This reach should contain a representation of the predominant habitat types including two or more pools characteristic of the system. The following steps describe measuring channel morphology variables (Figure 6.5).

1. Extend a measuring tape from the left bank stake (left side looking upstream) to the right bank stake.

2. Use a carpenter's level, Abney, or other leveling device to level the measuring tape (for large streams, a surveying level will be required to make these measurements). Since either the right or left stake may be lower than its opposite stake, it is useful to bring along a three to four foot long piece of rebar to drive into the ground adjacent to the lowest stake, and tie-off the measuring tape to this stake when leveling. After leveling the tape, take depth readings with the rod of the distance from the leveled tape to the ground. Record depth measurements at slope breaks in the bed on the cross section.

3. The locations of high and low flow shorelines must be noted in the profile survey. If profiles are made at the time of low streamflow, simply identify the present shorelines in the profile survey. If not, a visit back to the site during both high and low flow discharge can determine such locations. Simply walk along one side of the stream, and measure the horizontal distance from the stakes on that side to the shoreline of the stream. Those distances can then be noted on plots of the channel profile to obtain average widths and depths.

4. If site visits cannot be made during high streamflow, indicators of bankfull flow can be used to estimate locations of high flow in the channel.

At each cross-channel transect:

Complete the cross section survey and record data in the format presented in Table 6.5.

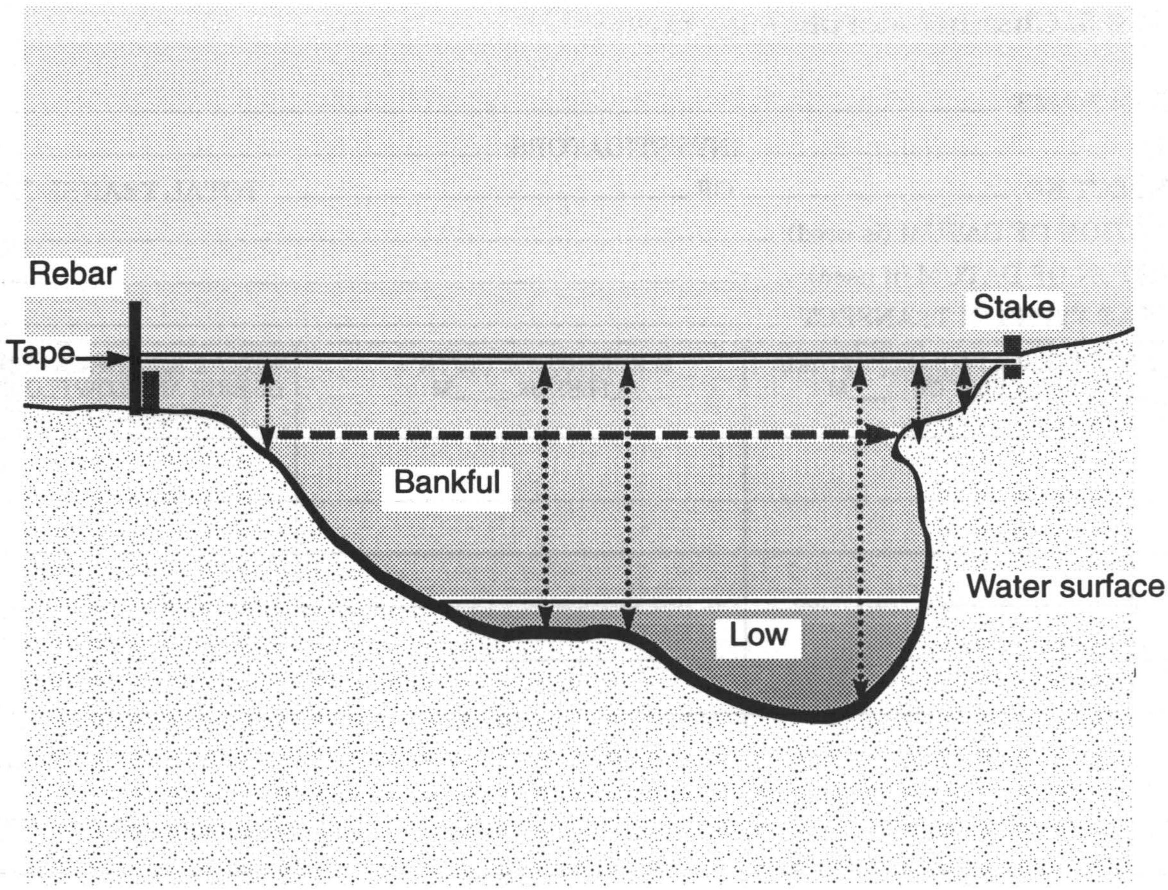


Figure 6.5. Channel profile cross section for width and depth measurements at bankfull and low flow

Table 6.5. Channel morphology survey

STREAM NAME: ____________________

DATE: ____________ INVESTIGATORS: ____________

TRANSECT NO. ________ OF ________ TOTAL TRANSECTS

ELEVATION OF DATUM (is used): ____________

LOCATION OF DATUM (if used): ____________

HABITAT TYPES IN TRANSECT: ____________

POINT #	DISTANCE FROM LEFT STAKE ____FEET OR ____M	ELEVATION, OR DEPTH ____FEET OR ____M	NOTES & IDENTIFICATION OF HIGH AND LOW FLOW H = high, L = low
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

COMMENTS

DATA ANALYSIS

Data from the survey can be used to determine the maximum depth, average depth, and ratio of width to maximum depth (or mean depth) for both low flow and bankfull levels. The elevation data are recorded in relation to the two stakes at either end of the transect. Because the locations of those stakes are permanently fixed on the bank, changes in channel morphology can be detected over time in relation to the elevations of the stakes. Thus, for monitoring purposes, it is important to measure depth relative to the two fixed elevations.

Data are then analyzed as follows:

1. On a graph paper plot each channel profile using the data from the field sheets. Scales in the vertical dimension can be exaggerated to increase the sensitivity of depth estimates. Show the locations of high and low flow by drawing horizontal lines representing the respective water surfaces.

2. Measure water width (W) at low flow and bankfull flow directly on the graph paper.

3. Calculate the cross-sectional area from the water surface to the ground level. Divide by the width to obtain the average depth.

4. Determine the mean channel characteristics for the monitoring site by averaging the water widths and average water depths, for all transects in the monitoring site.

To rate the condition of a degraded channel, divide the average width by the average depth (width/depth ratio), and compare the this value to a reference channel using the same ratio.

EQUIPMENT LIST

1.	Measuring rod - surveying rod or equivalent (at least 10 foot length)
2.	Waders
3.	Map of site
4.	Field data forms
5.	Measuring tapes
6.	Clip board

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E. STREAMBANK STABILITY

PARAMETER LIST

Monitoring parameters associated with this protocol are:

1. Streambank stability
2. Streambank cover
3. Undercut streambank
4. Streambank overhanging vegetation

OVERVIEW

Removal of streambank/riparian vegetation along with mechanical bank damage reduces the structural stability of the stream channel with several resultant negative impacts to fish productivity (Platts, 1990; Platts and Nelson, 1989). Reduction in bank cover related to overhanging vegetation, root vegetation, and undercut bank is correlated to reductions in fish production (Wesche, 1980; Binns, 1979; Sullivan et al., 1987). Streambank destabilization and resultant erosion can increase substrate embeddedness (Shepard, 1989; Nelson et al., in press; Hawkins et al., 1983). Increases in substrate embeddedness impair food production and block refugia for young trout (Rinne, 1990).

Parameters for monitoring livestock grazing effects on the stream channel should include bank stability to assess erosion and sedimentation as well as changes in channel morphology that reduce fisheries rearing space and cover. Bank stability is linked to cover factors that resist the forces of stream erosion. Cover may include deeply rooted bank vegetation, rocks, logs, and other resistant materials.

Fish use streambank areas in small streams for the protective cover they provide. Stable and covered banks control water velocities, provide shade for temperature control, and supply terrestrial foods needed to support salmonids (Platts, 1990, p I-24). Habitat cover provided by undercut banks and overhanging vegetation is estimated by a technique suggested by Lloyd (1986).

DEFINITIONS:

Streambank stability: Banks are unstable if they show indications of any of the following features (see Figure 6.6):

BREAKDOWN (obvious blocks of bank broken away and lying adjacent to the bank breakage).

SLUMPING or FALSE bank (bank has obviously slipped down, cracks may or may not be obvious, but the slump feature is obvious).

FRACTURE (a crack is visibly obvious on the bank indicating that the block of bank is about to slump or move into the stream).

VERTICAL AND ERODING (The bank is mostly uncovered as defined below and the bank angle is steeper than 80 degrees from the horizontal).

Otherwise, banks are stable.

Streambank cover: Banks are covered if they show any of the following features:

Perennial vegetation ground cover is greater than 50 percent.

Roots of vegetation cover more than 50 percent of the bank (deeply rooted plants such as willows and sedges provide such root cover).

At least 50 percent of the bank surfaces are protected by rocks of cobble size or larger.

At least 50 percent of the bank surfaces are protected by logs of four inch diameter or larger.

Otherwise, banks are considered uncovered.

Undercut bank: An undercut bank is defined as that bank which has been cut by the stream so that a protrusion of the upper portion of the bank overhangs the water surface. The water level does not influence this reading.

Overhanging vegetation: That bank with vegetation which protrudes over the water surface. Vegetation is within 12 inches vertically above the water surface.

DATA COLLECTION METHODS

Streambank stability

Streambank stability is estimated using a simplified modification of Platts, Megahan, and Minshall (1983, p. 13). The modification allows for measuring bank stability in a more objective fashion. This measure can be made rapidly without any specialized equipment. The lengths of banks on both sides of the stream throughout the entire linear distance of the representative reach are measured and proportioned into four stability classes as follows:

1. **Mostly covered and stable (non-erosional).** Streambanks are OVER 50% COVERED as defined above. Streambanks are STABLE as defined above. Banks associated with gravel bars having perennial vegetation above the scour line are in this category.

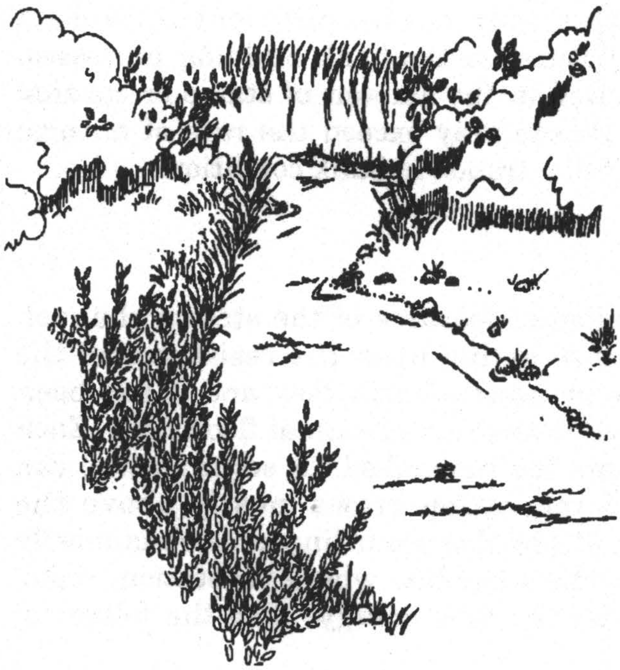
2. **Mostly covered and unstable (vulnerable).** Streambanks are OVER 50% COVERED as defined above. Streambanks are UNSTABLE as defined above. Such banks are typical of "false banks" observed in meadows where breakdown, slumping, and/or fracture show instability yet vegetative cover is abundant.

3. **Mostly uncovered and stable (vulnerable).** Streambanks are less than 50% COVERED as defined above. Streambanks are STABLE as defined above. Uncovered, stable banks are typical of streamsides trampled by concentrations of cattle. Such trampling flattens the bank so that slumping and breakdown do not occur even though vegetative cover is significantly reduced or eliminated.

4. **Mostly uncovered and unstable (erosional).** Streambanks are less than 50% COVERED as defined above. They are also UNSTABLE as defined above. These are bare eroding streambanks and include ALL banks mostly uncovered which are at a steep angle to the water surface.

The streambank must be envisioned as that part of the channel which would be most susceptible to erosion during high water events if vegetation were removed; therefore it represents the steeper-sloped sides of the stream channel. Bank cover is generally viewed at the vegetative greenline located below the bankfull level but above any natural undercutting bank scour (above the scour line). Using a measuring tape, measuring rod, or measuring wheel, record the length of streambank on both sides of stream in the representative reach represented by each of the stability classes.

Figure 6.6. Stream channel stability and cover indicators



Covered and stable

Covered and unstable

Uncovered and stable

Uncovered and unstable

Because streambank parameters can change during the livestock grazing period, the data form facilitates recording changes observed over the season or from season to season. Grazing intensity should not be sufficient to cause a seasonal change equal to or greater than natural streambank building processes. In many cases, more than 10 to 15% reduction in the amount of stable or covered streambank over the course of a grazing season may exceed the rate of natural streambank building and contribute to declining trends in bank condition.

Locating streambanks

Streambanks are defined by morphological features of the stream channel. They are created by the forces of streamflow acting upon the resistance of the channel to erosion. Streamflow forces are greatest at high flow and it has been shown that channel shapes are closely linked to the rate of annual flood flow. Each year the stream reaches a stage which scours the streambed. A scour feature can easily be recognized, because perennial vegetation grows mostly above the streambed eroded during the annual flood. Below this scour line, erosion is mostly a natural phenomenon. Banks form above the scour line where vegetation, roots, rocks, and other forms of resistance counter the flow energy. Use the following guidelines to locate banks for evaluation.

Locate the scour line in the stream reach. The scour line is at some elevation above the current water line. It can be located by examining features in the channel. The ceiling of undercut banks, the limit of sod forming vegetation, and the limit of perennial vegetation all clearly demark the scour line level.

View the scour line level along the entire length of the stream reach. The bank is that portion of the channel margin above the scour line at the steepest angle to the water surface.

On gravel and sand bars, the bank is often defined by the limit of sod or perennial vegetation, or by an indentation in the bar (local steepened area) just above the scour line. That small indentation or lip is the bank as defined in this procedure.

When the bank is not present due to excessive bar deposition or to streamside trampling the bank is classified "stable but uncovered."

Undercut banks or overhanging vegetation:

Using a measuring tape, measuring rod, or measuring wheel record the length of streambank on both sides of stream in the reach represented by undercut bank or overhanging vegetation. Use Table 6.7 to record overhanging vegetation and undercut banks. The same principles with respect to observed changes in bank stability over a single grazing season apply to undercut banks and overhanging vegetation as discussed above.

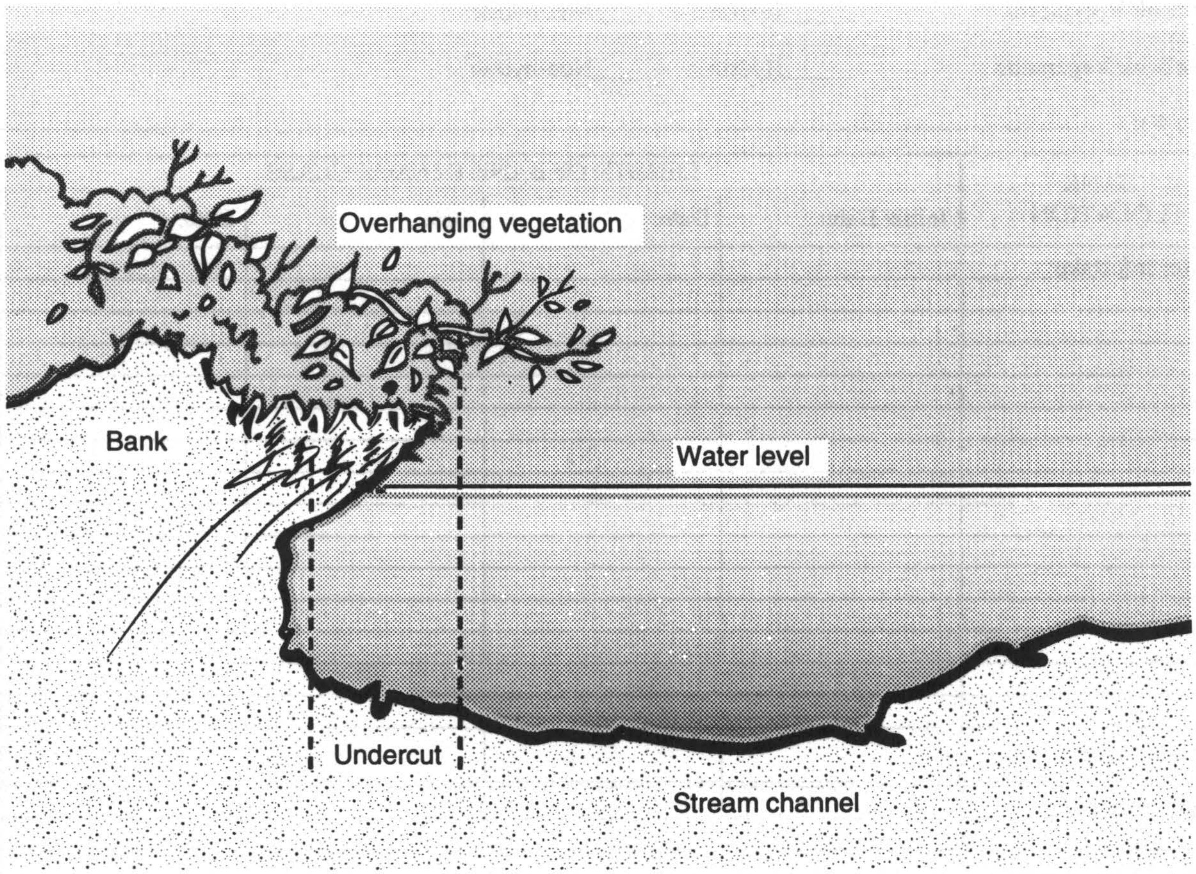


Figure 6.7. Channel cover: undercut banks and overhanging vegetation
(After C.J. Hunter 1991)

Table 6.6. Streambank monitoring form

Station name: ____

Drainage: ______________________ Investigator(s): ______________________

NOTE: Start at downstream left stake, proceed on that bank to upstream stake. Cross stream and proceed from directly opposite the upstream stake to directly opposite the downstream stake.

Units: _____Metric _____English

Left bank Vegetation: _____Hydric _____Non-hydric

Right bank Vegetation _____Hydric _____Non-hydric

Photo #'s: ____

BANK LOCATION	LENGTH OF BANK IN EACH CLASS			
	Initial Date:	Date:	Date:	Date:
Lower left stake				
Total left side				
Upper right stake				
Total right side				
Utilization:	0 %			

Bank classes: CS = Covered/Stable; CU = Covered/Unstable; US = Uncovered/ stable; UU = Uncovered/Unstable

Table 6.7. Undercut/overhanging bank monitoring form

Station name: ______________________________

Drainage: ______________________ Investigator(s): ______________________

NOTE: Start at downstream left stake, proceed on that bank to upstream stake. Cross stream and proceed from dire tly opposite the upstream stake to directly opposite the downstream stake.

Units: _____Metric _____English

Left bank Vegetation: _____Hydric _____Non-hydric

Right bank Vegetation _____Hydric _____Non-hydric

Photo #'s: ______________________________

BANK LOCATION	LENGTH OF BANK IN EACH CLASS			
	Initial Date:	Date:	Date:	Date:
Lower left stake				
Total left side				
Upper right stake				
Total right side				
Utilization:	0 %			

Bank classes: UB = Undercut bank OV = Overhanging vegetation

DATA ANALYSIS

The composition of the streambank relative to each of the four bank condition classes is calculated and reported as percent of each class. Thus each class percentage is calculated as follows:

$$CL\% = (LC/L) \times 100$$

where: CL% = percent in any class (classes are CS, CU, US, UU as defined above).

LC = length of bank in that class.

L = total length of bank evaluated.

During the grazing season, a change in the composition of any class can be measured using this equation. However, it is often more meaningful to represent the composition of just two parameters, total stable and total covered, thus:

$$\%stable = (CS + US)/L \times 100$$

where: CS = length of bank covered and stable
US = length of bank uncovered and stable
L = total length of bank evaluated

and:

$$\%covered = (CS + CU)/L \times 100$$

where: CS = length of bank covered and stable
CU = length of bank covered and unstable
L = total length of bank evaluated

These equations, representing the percentage of change by linear composition along the streambank, apply also to lengths of undercut and overhanging vegetation.

Similarity between the present and reference condition is calculated as the sum of the percentage of composition in common in each condition class. A reference site must be located and measured for purposes of comparison. The average condition of several reference sites could also be used in this scenario.

The calculation of similarity for bank cover is:

$$\%S = [\%Cr - (\%Cr - \%Ct)]/\%Cr \times 100$$

where: %S = Percent similarity or condition
%Cr= Percent covered at the reference
%Ct= Percent covered at the treatment

Substituting percent bank stability for percent bank cover, the same equation would apply to rating streambank stability in relation to reference (or potential) conditions.

Undercut bank and overhanging vegetation: The amount of undercut bank is also a percentage of the total length of streambanks. The calculation of similarity is:

$$\%S = [\%Ur - (\%Ur - \%Ut)]/\%Ur \times 100$$

Where:
- $\%S$ = Percent similarity or condition
- $\%Ur$ = Percent undercut bank + overhanging vegetation at the reference
- $\%Ut$ = Percent undercut bank + overhanging vegetation at the treatment

Note that percent similarity may exceed 100 when undercut bank plus overhanging vegetation at the treatment exceeds the reference site(s).

EQUIPMENT LIST

1. Steel rebar stakes, at least 4 per site
2. Waders
3. Map of stream segment
4. Field forms
5. Clipboard/notebook
6. Measuring tape, rod, or wheel to measure bank lengths

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F. SUBSTRATE FINE SEDIMENT

PARAMETER LIST

Parameters associated with this monitoring procedure include:

1. Percent substrate fine sediment
2. Substrate average particle size - D50

OVERVIEW

Streambank destabilization and resultant erosion can increase the amount of fine sediment on stream substrates (Shepard, 1989; Nelson et al., in press; Hawkins et al., 1983). Increased bedload sediment often originates from overgrazing by cattle (Platts, 1990). Such increases in substrate sedimentation have been known to impair aquatic food production and block refugia for young trout (Rinne, 1990). Salmonid survival at early life stages has been directly linked to the amount of surface fines in the substrate (Rich et al., 1992). Juvenile salmonids are dependent on clean substrate as cover, especially for over-winter survival. If this habitat is not available, they must either find other suitable habitat by migrating from the stream reach or find replacement habitat (Bustard and Narver, 1975a; Bustard and Narver, 1975b; Hillman, Griffith and Platts, 1986; Rieman and Apperson, 1989).

Fine sediments in streams move either in suspension in the streamflow or are bounced along the bottom (bedload). The size of the particle and the amount of energy in the stream determine which mode of transport will occur within a stream reach. Substrate problems for salmonids generally occur within stream reaches having low energy and higher concentration of coarse fines such as sand. In such cases, bedload is significant and often greater than suspended load. Small meadow streams dominated by smaller particles such as silt and fine sand often have enough energy to suspend these particles, but the materials return to the bed at obstructions and channel bends, infiltrate the cleaner spawning substrates, and block oxygen delivery to developing salmonid embryos.

The proportion of fine sediments on the substrate surface of a stream provides a good estimate of substrate habitat quality for salmonids. The percent of the surface area occupied by fine sediments can be effectively estimated using plot grids or by particle counting on pace transects. The latter method is called pebble counting and was originally described by Wolman (1954). The plot method allows for examining numerous points on the substrate of the stream in a short period of time, but only measures percent of the area in fines. Pebble counting also allows for examining numerous points on the substrate of the stream, but requires longer time to collect the samples. At each sampling point the observer must remove a particle from the stream and measure its diameter. Pebble counting provides an estimate of the percent of the substrate occupied by all particle classes, and not just percent fines. The substrate size distribution is important for determining the stability of the substrate and therefore the cause of reduced substrate quality or reduced pool volume.

Pebble counting and plot grid estimates only measure the areal or surface composition. Other techniques, such as cobble embeddedness, and substrate coring (Platts, Megahan, and Minshall, 1983), have been used to estimate the volumetric effects of sedimentation. These techniques are more time consuming than surface techniques. Because substrate sedimentation is highly variable in space over the stream bottom, numerous samples are required to adequately estimate the mean or describe differences between stations. At least one hundred individual samples are often required in pebble counting to adequately represent this measurement. Such intensity of sampling using cobble embeddedness measurement techniques, or depth coring would be prohibitive due to the time and cost of retrieving samples. The techniques presented here are assumed to be good surrogates for depth fines and embeddedness. Correlations between estimates are often observed at individual stations. Some coring and embeddedness estimations could be made to develop the desired correlation, but it is recommended that monitoring be focused on surface fines techniques because of their cost effectiveness.

Ocular methods for estimating surface fines and embeddedness have been tested by Torquemada and Platts (1988). While these simple techniques can provide a reasonable estimate, they require observer judgement and observer bias could be significant. This potential bias is probably inappropriate for purposes of time trend monitoring and multiple site comparisons. Therefore we do not recommend application of ocular methods for monitoring.

PEBBLE COUNTING

Data Collection Methods

Sampling is conducted on each of the cross-channel transects at the station to estimate the overall particle size distribution within the stream reach. At each transect, particles are selected from the substrate and measured to count the number of pebbles in each of several size classes. The data are recorded on the form in Table 6.8 which displays the standard substrate size classes used. The numbers of pebbles collected in the "silt/clay" and "sand" size classes determine the percent of fine sediments in the system.

Pace Methods: At each transect, the pebble count begins at bankfull stage on one bank and proceeds to the same stage on the other side of the stream. The observer paces across the transect and collects samples one step at a time. At each step, the observer reaches down to the tip of the boot and with the index finger extended, selects the first particle touched by the extended finger. In cold water conditions, use arm-pit length gloves. Look across and not down while taking a step and selecting the pebble so as not to bias the sample. The pebble selected should be that first touched by the center of the finger. If the side of the finger touches a pebble in interspaces between particles, the sample should be taken from below the interspace.

Each particle is recorded as a tally in one of the size classes on Table 6.8. To determine which class the pebble should be in, measure the length of the intermediate diameter of the particle. The intermediate diameter is found by observing first the longest diameter, and then the shortest diameter of the particle. The intermediate diameter should be found perpendicular to these axes. Think of the intermediate diameter as that axis which would allow the particle to fall through a sieve as it was agitated on the upper sieve surface. Particles too small to measure less than .1 inch, are classed as either sand or silt/clay. If the fine particles observed at that location do not feel grainy to the touch, record as silt/clay. Fine particles thinly coating the surfaces of larger gravels, pebbles, and boulders are NOT counted in the tally. Fines should have a depth of at least 1 inch to count as bed material.

Fixed Interval Method: For particles that cannot be picked-up from the stream bed (big rocks, armored pebbles, deep water) the tape line fixed interval sampling procedure is suggested. Extend a measuring tape between the two stakes on the transect. At fixed intervals along the tape line, usually 10 to 20 per transect, examine the substrate and estimate the particle size class at each location. A six inch square plexiglass plate fixed to a wood box frame makes a good substrate viewer. The box deflects agitation on the water surface and the plexiglass permits improved visual observation of the bottom. Particles sizes are estimated according to the intermediate diameter as observed from above. An 18 inch ruler is often used to measure the diameter of large particles. Particles in deep water are estimated by comparing their diameters to the observers known boot length. Selecting particles underneath the fixed interval on the measuring tape can be unbiased if the observer uses a rod to select the particle for measurement. At the appropriate location on the tape, extend the rod vertically down to the substrate. Avoid looking at the substrate until the rod touches ground. Then using the viewer, examine the particle directly beneath the center of the base of the rod. Record the particle size class as above.

DATA ANALYSIS AND INTERPRETATION

The tallies for each particle size class are summed and a cumulative distribution determined. In other words, the cumulative percent finer than each class is calculated. The graph in Figure 6.8 represents the cumulative distribution from the data in the example below. The graph is constructed as follows:

1. The X axis represents cumulative percent of particle sizes up to 100%.

2. The Y axis is particle size in millimeters and is on a logarithmic scale.

3. Samples are partitioned into size classes on the field data form. The smallest size class is silt/clay and is represented by a maximum size of 1 mm. The next class is sand, from 1 to 2.5 mm. The next class is medium gravel which has a maximum size of 15 mm, and so forth.

4. Each size class represented in the pebble count survey is plotted on the graph according to its cumulative proportion of the total sample size. Thus, if 100 pebbles are obtained in a typical survey, and 25 of them are silt/clay, then 25 percent of the total sample is smaller than silt/clay. If 10 pebbles in the survey are sand, then 25 plus 10 percent = 35 percent of the sample is smaller than sand.

From the cumulative frequency graph, the size of particles, smaller than the value corresponding to a frequency of occurrence can be determined. In Figure 6.8, the particle size for which 50 percent of all measured particles are smaller is 11 mm.

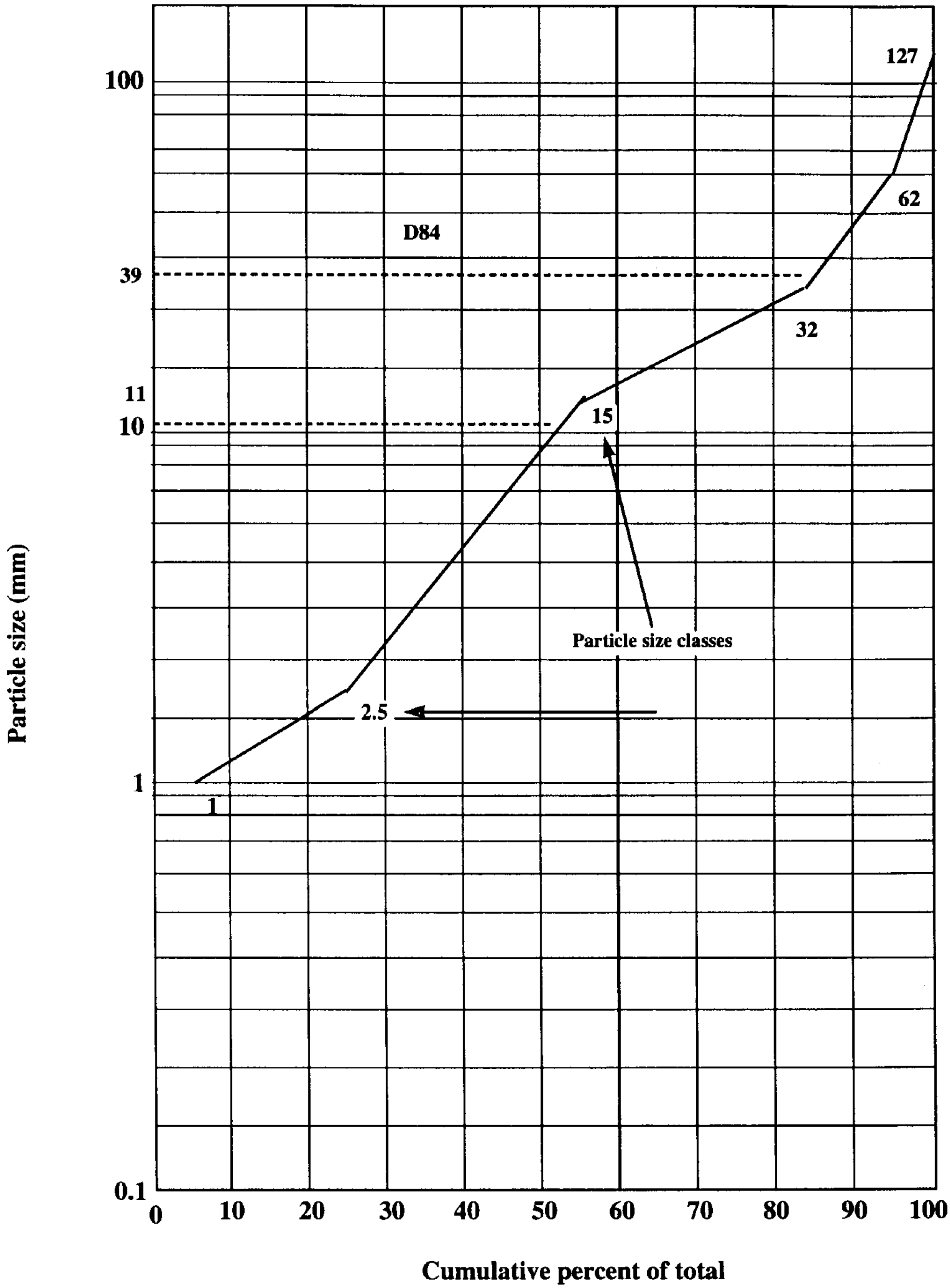

Figure 6.8. Cumulative frequency diagram for Wolman pebble count

GRID METHOD

Data Collection Method

Pebble counting can, in some cases, underestimate surface fine sediment composition. Because particles are selected from above the bed, fines located in interstitial spaces between larger particles can be missed. The grid method of measuring the aerial composition of surface fines can be used to avoid such biases. The area of fines on a known area can be estimated using a procedure similar to dot counting area on a map.

Three sampling grids are located on each transect in the monitoring site (Figure 6.9). Location of the plot on the transect is determined by generating random numbers between the transect endpoints and centering the grid at those points on the transect.

At each sampling point, the percent of the grid area in 100% fines is estimated. Fines are defined as that fraction of substrate less than .6 inch (15 mm) in diameter. It is useful to separate these into two classes to assess relative differences between fines blocking emergence (coarse sand) and fines filling habitat. They are defined as:

Fine sand - less than .1 inch (2 mm) diameter
Coarse sand - .1 to .6 inch (2 - 15 mm) diameter.

Intersections in the grid directly over areas of fine sediment are counted. A 2 inch diameter grid covering a plot area of 2 feet square provides 144 intersections (12 X 12) for assessment of percent fines. Tally the total number of intersections over fine and coarse sands and record the data on the form in Table 6.9.

Subsequent monitoring requires revisiting the same transects and plots as previously established. At each transect, the exact location of the previously sampled plots must be relocated. Make sure the measuring tape is always extended from the right bank, looking upstream, to the left bank so that zero distance is at the right stake.

DATA ANALYSIS AND INTERPRETATION

Percent surface fines collected using the plot data are simply averaged over all plots sampled for both coarse and fine sand sizes. The percent fines on any one plot is equal to the number of intersections counted over sand divided by the total number of intersections on the grid.

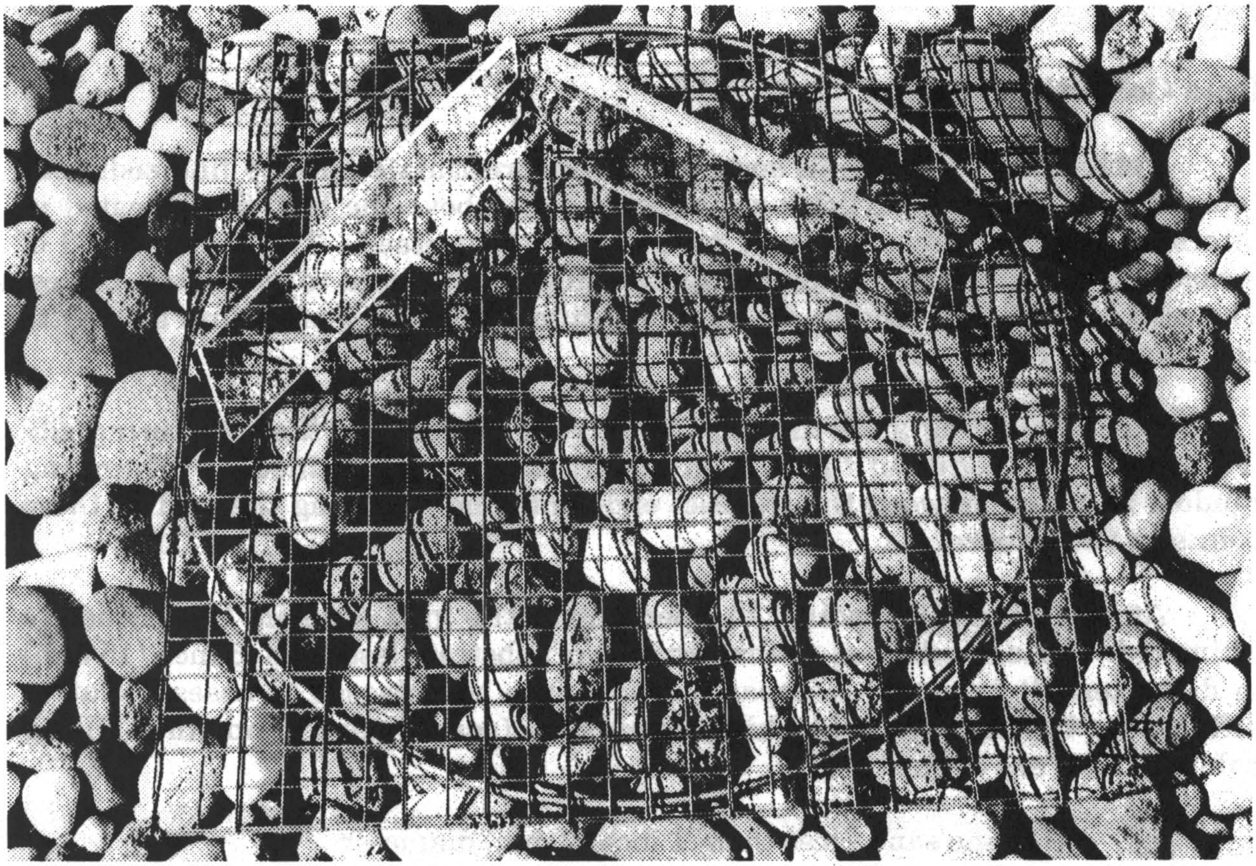

Figure 6.9. Grid for measuring percent surface fine sediment

EQUIPMENT LIST

1. Hip or chest waders
2. Arm length rubber gloves (pebble counting in cold water)
3. Measuring tape, tag line, or equivalent (plot grid method)
4. Sampling grid (plot grid method)
5. Data forms
6. Programmable hand calculator or table to obtain random numbers for plot location (plot grid method)
7. Ruler or scale (pebble counting)

Table 6.8. Pebble count for particle size distribution

Stream/riparian reach name: ______________________

Date: ____________ Examiners: ______________________

SIZE CLASS	TRANSECT #										TOTAL BY CLASS
	1	2	3	4	5	6	7	8	9	10	
Silt/Clay											
Sand < .1 In. (<2.5 mm)											
.1 - .6 In. (2.5 - 15 mm)											
.6 - 1.25 In. (15 - 30 mm)											
1.25 - 3 In. (30 - 75 mm)											
3.0 - 6 In. (75 - 150 mm)											
6 - 12 In. (150 - 300 mm)											
12 - 24 In. (300 - 600 mm)											
24 - 36 In. (600 - 900 mm)											
36 - 80 In. (900-2000mm)											
80 - 120 In. (2000-3000mm)											
TOTALS											
HABITAT TYPE (p) pool (r) riffle (g) glide (rn) run											

Table 6.9. Surface fine sediment.

Stream/riparian reach name: ______________________________

Date: ______________ Examiners: ______________________________

Total number of intersections in plot grid: ______________________________

TRANSECT NUMBER	PLOT # AND LOCATION - fine sand/coarse sand/distance									AVERAGE FOR EACH TRANSECT	
	1 FS*	1 CS*	1 Dist*	2 FS*	2 FS*	2 Dist*	3 FS*	3 CS*	3 Dist*	FS*	CS*
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

* FS - number of intersections over fine sediment (< .1 inch or 2 mm)
* CS - number of intersections over coarse sediment (.1 to .6 inch)

Dist - record the distance from the right stake (looking upstream) to the center of the plot

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G. POOL QUALITY

PARAMETER LIST

Parameters associated with this monitoring procedure include:

1. Pool quality
2. Pool condition

OVERVIEW

Fish abundance is related to the diversity of habitats and number and quality of in-stream pools in stream environments (Kozel and Hubert, 1989a; Moore and Gregory, 1989). Pool filling and de-stabilization as a result of sedimentation of the substrate can alter habitat structure and diversity important to fish (Lisle, 1987).

Detecting pool changes within the channel, especially a decrease of habitat diversity and quality over periods of increasing substrate sedimentation, provides a means of monitoring beneficial use impairment in streams used for rearing salmonids. Changes in habitat diversity are often associated with adverse impacts to key rearing habitats or pools. Pool quality is largely a function of the amount of cover available in slow velocity waters. Fish depend heavily on cover for refuge and security. Survival and health of aquatic communities can be determined by pool quality, when cover in low velocity waters is limited.

DEFINITIONS

<u>POOL:</u> Pools have these characteristics (Platts, Megahan, and Minshall, 1983; Bisson et al., 1982):

- Reduced water velocity
- Water depth is greater than surrounding areas
- The water surface gradient at low flow is often near zero
- The bed is often concave in shape and forms a depression in the profile of the stream's thalweg
- Pools are formed by features of the stream that cause local deepening of the channel. Deepening results from lateral constrictions in flow or by sharp drops in the water surface profile. Examples include:

- Plunge pool, created by water passing over or through a complete or nearly complete channel obstruction, scouring out a basin below. They are often associated with large debris and are usually macro-habitat.

- Dammed pools, impounded upstream of a complete or nearly complete channel blockage caused by log jams, beavers, rockslides, boulders, etc. They are usually macro-habitat.

- A meander or corner pool is a lateral scour pool resulting from a sudden shift in channel direction and occurs along the outcurves of channel meanders. These are usually macro-habitat.

- Backwaters caused by an eddy along the channel margin or by back-flooding upstream from an obstruction such as large woody debris, boulders or root wads. These are usually micro-habitat.

- Trenches or slot-like depressions formed usually in bedrock channels in long linear shapes. These are usually micro-habitat

- Lateral scour around local obstructions such as wing deflectors, boulders, or individual logs. These are usually micro-habitat.

DATA COLLECTION METHODS

A survey such as that suggested by Hankin and Reeves (1988) is recommended for assessing quality of pools in a reach of stream. Following is a brief summary of the data collection steps.

1. The observer proceeds along the length of the stream channel sequentially identifying and classifying the stream channel into different habitat types based on geomorphic and flow characteristics.

2. All pools encountered during the reach survey are evaluated. At each pool, fill out a data sheet characterizing pool quality (Table 6.10). The following factors are assessed in the survey:

a. **Depth**: Depth is defined as residual pool depth or maximum depth of the pool minus pool spill-out depth (Figure 6.11). Record a single digit code for the depth as follows:

Depth < .5 feet, code = 0.
Depth > .5 and < 1.5 feet, code = 1.
Depth > 1.5 feet, code = 2.

b. **Substrate**: Record the substrate code as follows:

Dominated by gravel size material or smaller - (< 2.5 inches) then code = 0.
Dominated by cobble sized material - (> 2.5 inches and < 10 inches) then code = 1.
Dominated by boulder size material - (> 10 inches) then code = 2.

c. **Overhead cover**: Record the code for overhead cover (OC) created by terrestrial vegetation or turbulence.

If OC < 10 percent of surface area of pool, then code = 0.
If OC is between 10 and 25 percent of the surface area, code = 1.
If OC > 25 percent of the surface area, code = 2.

d. **Submerged cover**: Record the code for submerged cover (SC) created by large organic debris, small woody debris, and other forms below or on the water surface.

If SC < 10 percent of surface area of the pool, then code = 0.
If SC is between 10 and 25 percent of the surface area, code = 1.
If SC > 25 percent of the surface area, code = 2.

e. **Bank cover**: Record the code for bank cover (BC) created by undercuts in the bank, stumps, large roots, and other along the pool margins.

If BC < 25 percent of the total bank length along the pool, then code = 0.
If BC is between 25 and 50 percent of the total bank length, then code = 1.
If BC > 50 percent of the total bank length, then code = 2.

The quality for the pool is then determined by summing the codes over all five factors (Figure 6.10). For example, a pool received these ratings: depth = 2, substrate = 0, overhead = 2, submerged = 0, and bank = 1. The pool complexity equals: 2 + 0 + 2 + 0 + 1 = 5. Pool quality ratings range between 0 and 10 with low values indicating low quality.

DATA ANALYSIS

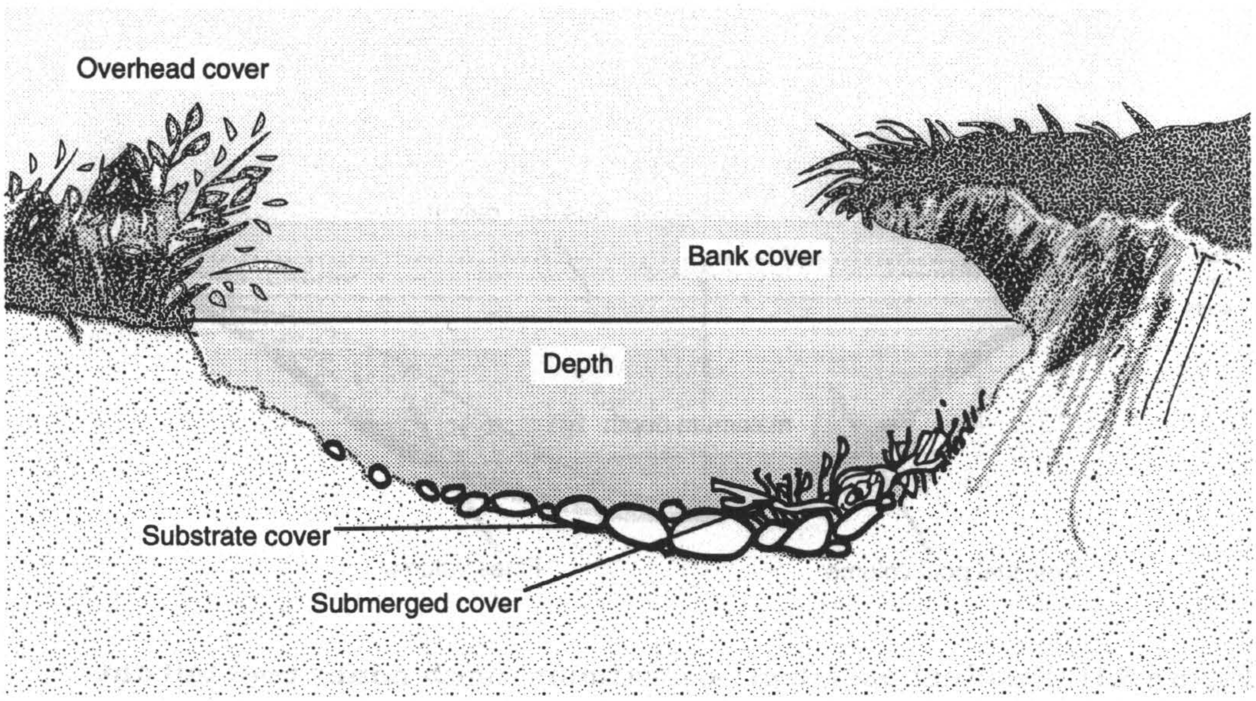
Pool quality index: The pool quality index is a value between 0 and 10, with 10 highest complexity (quality) and 0 lowest quality, as defined above. It is the average of pool quality ratings over all pools evaluated. This is a qualitative rating. The subjectiveness of the rating can be minimized by measuring depth, length of undercut bank, length and width of overhanging vegetation and other cover components of the pool. An individual pool can be identified with a marked stake and measurements recorded by pool number. Photographs of individual pools help to assess changes in quality over time.

Pool condition index: A condition index can be derived by comparing the similarity of pool complexity at an impacted site with an unimpacted or lightly impacted reference site. The similarity index is:

$$\%S = [PQr - (PQr - PQt)]/PQr \times 100$$

Where: %S = Percent similarity or condition
PQr = Pool complexity at the reference
PQt = Pool complexity at the impacted site

High quality pool



Low quality pool

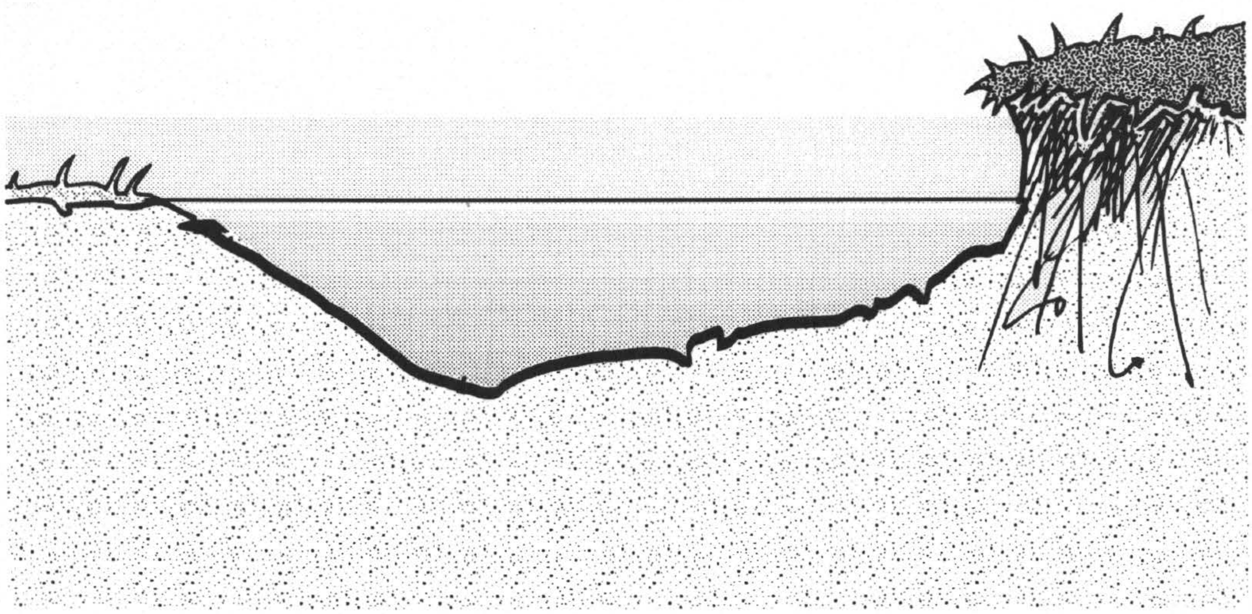


Figure 6.10. High quality pool compared to poor quality pool
(After C.J. Hunter 1991)

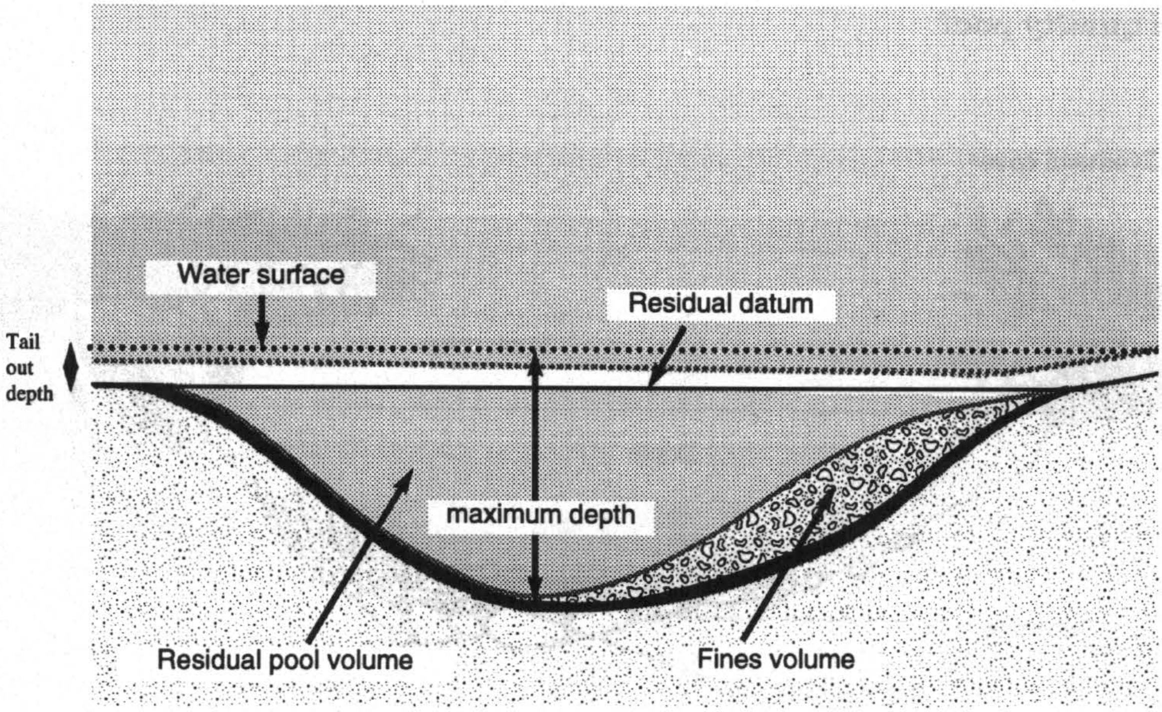


Figure 6.11. Residual pool depths, maximum depth minus pool tail out depth

Table 6.10. Pool quality index field form

POOL COVER TYPE	POOL NUMBER										
	1	2	3	4	5	6	7	8	9	10	TOTAL
HABITAT UNIT #											
DEPTH											
SUBSTRATE											
OVERHEAD											
SUBMERGED											
BANKS											
TOTAL FOR HABITAT UNIT											

CODES:

1: Depth:
- <.5 feet, code = 0
- between .5 and 1.5 feet, code = 1
- > 1.5 feet, code = 2

2: Substrate:
- gravel size material (< 2.5 inches), code = 0
- cobble size material (2.5 -10 inches), code = 1
- boulder size material (> 10 inches), code = 2

3: Overhead cover:
- < 10 percent of the surface of the pool, code = 0
- 10 - 25 percent of the surface area, code = 1
- > 25 percent of the surface area, code = 2

4: Submerged cover: large organic debris, small woody debris, and other forms below or on the water surface
- < 10 percent of the surface of the pool, code = 0
- 10 - 25 percent of the surface area, code = 1
- > 25 percent of the surface area, code = 2

5: Bank cover: Undercuts in the bank, stumps, large roots, and other along the pool margins
- < 25 percent of the length of the bank, code = 0
- 25 - 50 percent of the bank length, code = 1
- > 50 percent of the bank length, code = 2

EQUIPMENT LIST

1. Measuring rod - surveying rod or equivalent (at least 10 foot length)
2. Waders
3. Map of reach, preferably topographic, scale 1:24,000 or larger
4. Field forms
5. Habitat type keys
6. Clipboard/notebook
7. Measuring tapes

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H. STREAMSIDE VEGETATION

PARAMETER LIST

Parameters associated with this monitoring procedure include:

1. Vegetation composition (Green Line)
2. Woody species regeneration (age class)
3. Vegetative utilization (herbage stubble height)

OVERVIEW

Removal of riparian vegetation reduces habitat quality, resulting in negative impacts to fish productivity (Platts and Nelson, 1989). Reduction in bank cover related to overhanging vegetation, root vegetation, and undercut bank has been correlated to reduced fish production (Wesche, 1980; Binns, 1979; Sullivan et al., 1987).

Because riparian areas are usually grazed more heavily than adjacent uplands, overgrazing can lead to elimination of the more desirable, deep-rooted hydric plants (Platts and Nelson, 1985; Platts, 1990). Cattle feed on herbaceous riparian plants, browse shrubs, and trample valuable species thereby reducing their vigor and dominance on a site (Platts, 1990). Though changes are usually slow and go unnoticed, the long-term effect is often significant. Altered systems are eventually exposed to a large streamflow event, resulting in adverse modification of the channel and aquatic habitats.

A very common vegetative conversion resulting from livestock grazing in riparian zones is the replacement of natural grasses with Kentucky bluegrass (Platts, 1990). Also common is the conversion of native willow shrubs to grasses and forbs. Sedges and willows provide optimum stream habitat conditions because deep roots provide excellent bank stability and underbank cover, and the dense above-ground biomass often provides excellent overhead cover.

Streams which provide the best conditions for fish are those with dense, vigorous, and diverse riparian vegetation (Platts, 1991). Dense vegetation provides shade, energy (nutrients and food), and erosion resistance. Good plant vigor assures longevity of the plant community and resilience in times of stress. Diversity of plant communities creates complexity in aquatic habitats. As shrubs are added to grass-dominated riparian zones, their roots greatly increase cover quality and the shrubs contribute leaf litter that diversifies the food base. Trees added to shrub/grass riparian zones increase the amounts of wood, as roots or fallen limbs and trunks, that provide cover and complexity to the aquatic system.

Utilization is tradionally described as a percent of forage removed. A problem with this method is the difficulty of evaluating or visualizing something that has already been removed. Basing proper use on plant residue or stubble height may be preferable because the amount of herbaceous plant residue left has the greatest impact on plant health and soil and watershed protection (Valentine, 1990). Measuring the stuble height of herbaceous vegetation at the end of the grazing and growing season is an easy, rapid method of determining if sufficient herbaceous biomass remains to sustain desirable plant communities, maintain plant vigor, provide for a functioning flood plain, and protect the streambank. Clary and Webster (1989) suggest that going into winter, a herbage stubble height of four to six inches is enough vegetative biomass on the Green Line and floodplain to protect streambanks and flood plain functions. A site-specific stubble height objective will depend on the charateristics of the individual species and the sensitivity of the resource.

To estimate streamside vegetation conversion, the Green Line and woody species regeneration methods of monitoring are used, as documented in USDA Forest Service (1992) and Cowley (1992). A recent BLM publication provides a detailed monitoring protocol for Green Line riparian-wetland monitoring (USDI Bureau of Land Management, 1993.) Monitoring plant residue using stubble height is described in detail in Cowley (1992).

DEFINITIONS

Ecological succession or plant succession: The process of vegetational development in which plant communities progress from a lower to a higher ecological status.

Potential natural community: The combination of plant species that would result if ecological succession was completed without interruption.

Ecological status: The degree of similarity or comparison between current vegetation and the Potential Natural Community for the site.

Green Line: The first perennial vegetation above the stable low water line of a stream or water body.

Utilization: The amount of vegetation removed by a grazing animal, expressed as a percentage of the vegetation or a level such as light, moderate, or heavy.

Woody species: Plant species classified as shrubs and trees.

DATA COLLECTION - GREEN LINE METHODS

Vegetation Composition

The Green Line method provides an estimate of the composition of vegetation along the edge of the stream or waterbody. Measurement in this location within the riparian area provides indication of the effect of grazing on stream habitat. The procedure requires identifying each vegetation community type along the Green Line adjacent to the stream (Figure 6.12). Community types are an aggregation of all plant communities with similar structure and floristic composition. A sample listing of community types and plant identification keys are listed in the Reference section. The user should obtain the key(s) most applicable to the monitoring site location.

Use the Field Data Sheet in Table 6.11 to record data in the Green Line survey as follows:

1. Extend a measuring tape along the Green Line starting at the head stake in the monitoring reach. Make recordings along the entire study reach then cross the stream and do the same along the opposite bank.

2. Measure and record the length of each community type encountered. Record to a resolution of one foot.

3. Compute the total number of feet (or meters) of each community type along the Green Line. Determine the composition of each community by dividing its total length by the total Green Line length evaluated.

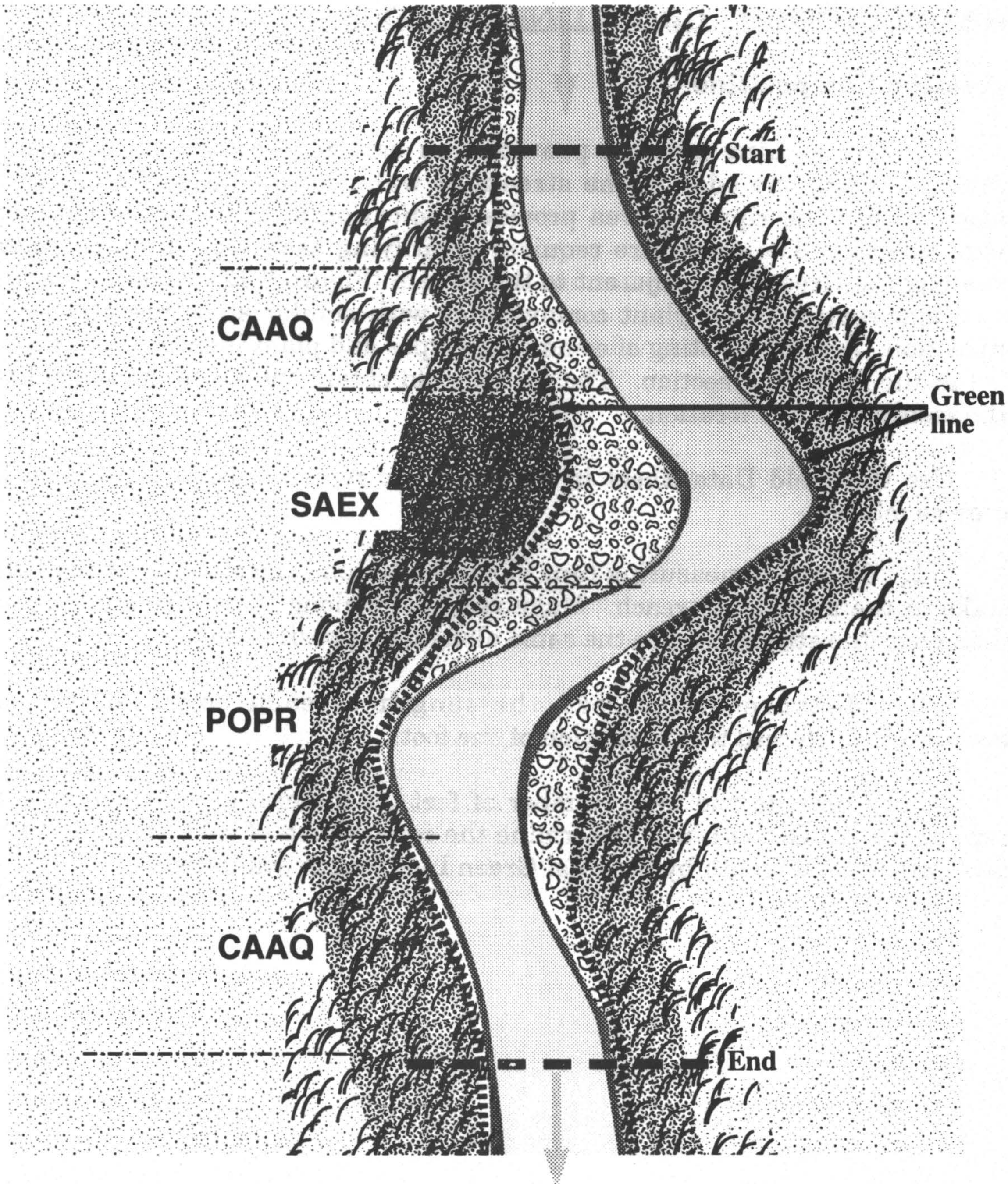

Figure 6.12. Location of the Green Line in relation to the water's edge and to sandbars. Community types shown on left bank only.

Table 6.11. Riparian Green Line vegetation field form

Stream/riparian reach name: ______________________ Date: __________

Drainage: ______________________ Photo#: __________

Examiners: ______________________

Location: ______________________

RIPARIAN GREEN LINE COMMUNITY TYPES TRANSECT DATA											
COMMUNITY TYPE	DISTANCES					Feet ______ or Meters ______					
	*1	2	3	4	5	6	7	8	9	10	TOTAL
TOTAL FEET:											

NOTES ______________________

*Transect number (record length downstream of the indicated number)

Woody Species Regeneration

A good indicator of vegetation trends along the Green Line is the composition of woody species age classes. Regeneration of woody species can be reduced by heavy browsing on young age class woody plants. A high amount of sprouts or young plants indicates an upward trend in shrub-dominated riparian types.

This monitoring method is applicable to areas with shrubs or shrub potential. The Green Line adjacent to the stream is where regeneration of woody plants is most likely to occur. Woody species along the Green Line are counted and placed in one of five age classes defined by the number of stems on each plant as follows Figure 6.13):

Number of Stems	Age Class
Number of stems = 1	Sprout
Number of stems = 2 to 10	Young
Number of stems > 10, > 1/2 of plant alive	Mature
Number of stems > 10, < 1/2 of plant alive	Decadent
Number of stems > 1, no stems are alive	Dead

Note: This system does not apply to sandbar willow (Salix exigua) and cottonwood species. For these, count the total number of live sprouts as young. They grow in single stems.

Use the field data form shown in Table 6.12 to record woody species age classes as follows.

1. Begin at the head or marker transect in the monitoring stream reach and proceed along the Green Line as described in the previous method. The method requires using a six foot pole with the center of the pole clearly marked.

2. Walk along the Green Line holding the center of the six foot pole directly over and perpendicular to the greenline. Record the numbers of woody plants and their age classes located under the pole. The six feet of pole will be extended to either side of the Green Line.

3. Total the number of each species of shrub in each age class encountered in the survey. Record the composition of each age class by dividing the number in that class by the total number of stems counted. Record the composition of each species by dividing the number of that species by the total number of stems counted.

Table 6.12. Woody species regeneration field form

Stream/riparian reach name: ______________________ Date: __________

Drainage: ______________________ Photo #: __________

Examiners: ______________________

Location: ______________________

GREENLINE WOODY SPECIES AGE CLASS DATA						
SPECIES	NUMBERS OF INDIVIDUAL PLANTS					
	Seed/sprout	Young/sap	Mature	Decadent	Dead	Total
TOTAL						

NOTES

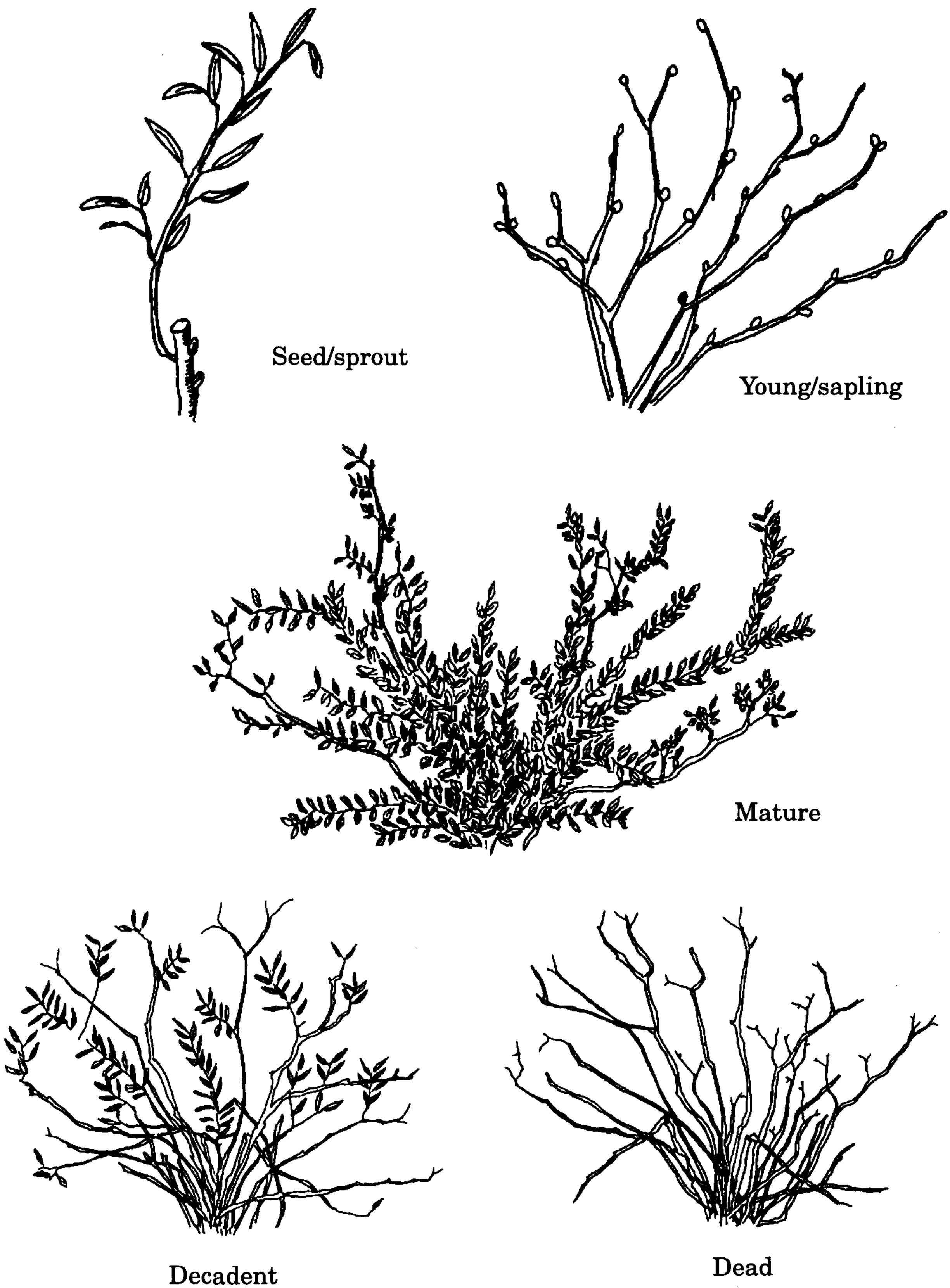

Figure 6.13. Woody species age classes.

DATA ANALYSIS - GREEN LINE AND WOODY SPECIES REGENERATION

Vegetation status is defined as the similarity of composition between current Green Line vegetation and the potential vegetation or the desired future condition (USDA, 1992). The vegetation condition of the reference site or sites should be at or near the potential natural community condition (PNC). If so, the ecological status will reflect the similarity between the study site and the PNC. If the condition of the reference site is below PNC, then similarity is referred to as the Resource Value Rating. Even if the reference site is below PNC, such sites may be at or near a "desired future condition." In this case, the Resource Value Rating will reflect the similarity between the study site and the desired future condition.

The following method is used to determine percent similarity:

1. Determine the composition of vegetation (or woody age classes) on the Green Lines of both the study site and the reference site(s). Express in percent as described above.

2. Determine the composition amount in common between study and reference site(s).

3. Total composition amount in common.

The following examples serve to demonstrate the technique:

Example 1. Vegetation Resource Value Rating or Ecological Status

Vegetation Community Type	Desired Future Condition or PNC (%)	Treatment Site (%)	Amount in Common
Booth willow(SABO)	35	5	5
Water sedge(CANE)	45	10	10
Blue grass(POPR)	10	65	10
Booth willow/bluegrass	10	20	10
Totals	100	100	35

Similarity = 35%

Example 2. Woody Species Resource Value Rating

Woody Species Age Class	Desired Future Condition or PNC (%)	Treatment Site (%)	Amount in Common
Sprouts	40	5	5
Young	30	10	10
Mature	15	25	15
Decadent	10	35	10
Dead	5	25	5
Totals	100	100	45

Similarity = 45%

VEGETATION UTILIZATION - HERBAGE STUBBLE HEIGHT

Measuring the amount of stubble left on the plants at the end of the grazing season is easy and rapid. Such measurements reflect the amount of grazing use taking place as well as any regrowth on plants, if use ends before the growing season ends.

The following describes the method for estimating average stubble height in the study reach. Use Table 6.13 to record data as follows:

1. Extend a measuring tape along the Green Line beginning at the head stake, as described for vegetation composition. Divide the Green Line length on each side of the stream by 50 to determine the spacing of samples on the Green Line. If the length on one side of the stream is 100 meters, stubble height will be measured every 2 meters along the tape.

2. Measure the heights of herbaceous vegetation including forbs, grasses, and grass-like plants at each of the 50 locations on each side of the stream. Do not include woody species.

3. Measure the height of the perennial herbaceous vegetation nearest the point on the tape. If there is no perennial hebaceous vegetation at the transect point, select the closest perennial herbaceous plant within a 180° arc in front of the observer and one half the distance to the next sampling point. Record "no vegetation" if it does not exist. Record all readings by species and height.

4. Record the total vegetation height, divided by the number of sample points for each species, to obtain the average stubble height by species. Then average the stubble height for all species to obtain an overall average.

The method described above is based on upland species which often occur in tufts and individual stems. In a meadow situation, the plant density is often too great to efficiently record individual stems and it may not be possible to identify individual plants (Warren Clary, personal communication 1993). In these situations, an alternative method is to record average stubble height classes by transect segment, such as by each 10 cm length. Stubble height is not recorded by species.

Table 6.13. Herbage stubble height field form

Stream/riparian reach name: ______________________________ Date: ______________

Drainage: ______________________________ Photo #: ______________

Examiners: ____

____

DISTANCE ON TAPE	STUBBLE HEIGHT		DISTANCE ON TAPE	STUBBLE HEIGHT	
	CT*	Inches		CT*	Inches
TOTAL:			TOTAL:		

COMMUNITY TYPE	AVERAGE STUBBLE HEIGHT

OVERALL AVERAGE STUBBLE HEIGHT = ______________

*CT - Community type

EQUIPMENT LIST

1. Measuring tapes (suggest minimum of 100 meters or 300 feet)
2. Waders
3. Six foot pole marked in the center
4. Field forms
5. Vegetation and community type keys
6. Clip board

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I. ESTABLISHING PERMANENT PHOTO POINTS

OVERVIEW

Photographs provide an excellent visual representation of conditions at a given point in time. Photographs supplement data collection at a monitoring site, and provide a minimum monitoring effort at other sites where data can not be collected. Photography, however, does not provide sufficient data alone to evaluate objectives. Rather photographs indicate only an upward, downward, or static trend in woody vegetation (Meyers, 1987) and streambank stability and cover. Recovery of vegetation can be extremely rapid where streams carry substantial loads of silt during high flows. However, initial vegetation "expression," obvious in photographs, should not be confused with vegetation "succession" required for stream ecosystem health (Elmore and Beschta, 1987).

Photography is easy and inexpensive, but still requires careful planning to provide meaningful information on condition and trends. Consistency is necessary to assure that photographs taken over time are comparable. The photo point procedure should describe use of the same camera, lens, film type, tripod height, and light conditions. Vertical and horizontal landmarks should be permanent, metal stakes or fenceposts, to assure the same photo can be repeated by different observers over time. The photo point locations need to anticipate growth of riparian vegetation and potential for obscuring future views.

DEFINITIONS

Profile board: The profile board is one-third meter by 2.5 meter plywood board marked in 0.5 meter intervals of alternating black and white (Figure 6.14).

DATA COLLECTION PROCEDURE

Meyers (1987) described a procedure for determining trends in woody riparian plants using a profile board and photographs. This method can be adapted to establish permanent photo points at stream channel cross-sections for detecting changes in streambank cover, stability, and riparian vegetation recovery.

1. Site selection and establishment

On monitoring sites, take photographs upstream and downstream at the first and last cross-channel transects (See Figure 4.1). Take the photos from the side of the stream that most effectively shows the important characteristics. A profile board placed 50 feet from the photo point, within three feet of the water's edge, provides a comparative reference for change over time.

Select photo points at other sites to illustrate particular problems, management solutions, or as a reference location for photo points. Place a permanent marker, such as a steel post or rebar, at the camera location. Locate a second marker where the profile board will be located.

Include permanent landmarks such as ridge lines in the photo to assure that the scene can be relocated by a different observer. A clipboard or chalkboard can be placed in the photograph with date, time, and station location. Document photo points and post and rebar locations in detail. Record locations on 7° minute quadrangle and aerial photos. Include prints in the documentation which can be taken in the field by subsequent observers.

2. Kodachrome™ slide film (or equivalent) is recommended because the dyes in it are more stable than other types and the photos retain the true colors longer (Jones, 1992). Slides are valuable for use in slide presentations for groups. High quality prints made from the slides can be used in files and for other needs.

A neutral gray card (18 percent gray) may be used to help identify the photo point in the picture and obtain true colors from film processing. Gray ranging from 15 to 25 percent is acceptable.

DATA ANALYSIS

Photo points are intended to supplement more quantitative monitoring methods. Slides can be compared over time to detect changes in streambank and riparian condition.

Meyers (1987) describes methods to calculate vertical foliar cover for woody riparian species using the profile board and photographs. This document should be consulted for additional description of the methods.

EQUIPMENT LIST

The following equipment is needed for this monitoring procedure.

1. Camera, film, and tripod
2. Vegetation profile board
3. Permanent stakes
4. Measuring tape and clip board

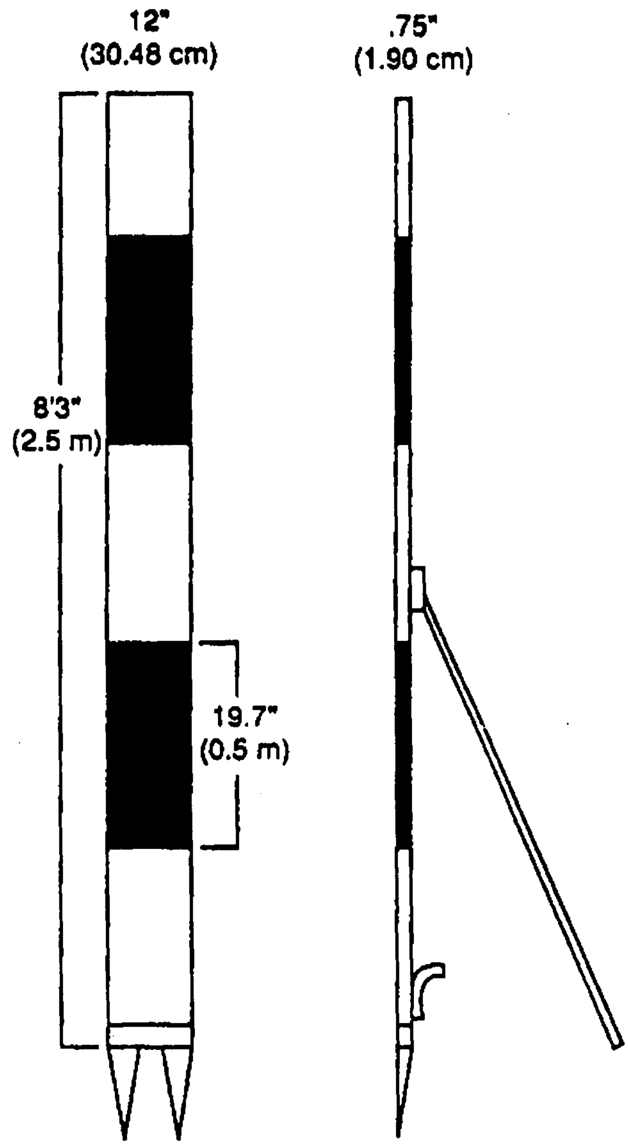

Figure 6.14. Vegetation profile board

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J. BIOMONITORING: BENTHIC MACROINVERTEBRATES

INTRODUCTION

Macroinvertebrate communities are useful for monitoring biological integrity of streams since they function as integrators of pollution over time and are a direct measure of beneficial uses (aquatic life support). There has been an increase in use of macroinvertebrates as water quality indicators due to development of Rapid Bioassessment Protocols (RBPs) and improved methods of data analysis using biotic indices and multiple metrics.

A detailed description of biomonitoring protocols is beyond the scope of this document; therefore, this section will refer to macroinvertebrate procedures that are currently available and may be useful for assessing biotic integrity of streams influenced by grazing activities.

OVERVIEW

Few specific studies have evaluated grazing impacts on aquatic macroinvertebrates. Rinne (1988) reported increased densities and biomass of more tolerant forms of macroinvertebrates in grazed reaches when compared to areas where livestock had been excluded. However, the study design did not allow separation of livestock impacts from linear changes in stream habitat and therefore the results were not conclusive. Intensive grazing, which opened the riparian canopy and decreased shade, increased periphyton and shifted the benthic fauna to more tolerant forms (Quinn et al., 1992). Benthic communities in grazed areas may be expected to respond to sediment and nutrients in a manner similar to other nonpoint source activities. Sediment from agricultural runoff (Lenat, 1981), logging operations and residential development (Lemly, 1982), and road construction (Lenat, 1984) altered benthic macroinvertebrate communities; generally, density of intolerant species decreased and tolerant species increased. Adams (1992) demonstrated reductions in biological conditions using Rapid Bioassessment Protocol III due to sediment impacts from poor logging practices. Burton (1993) found Percent EPT and Percent Peltoperlidae decreased, and percent Chironimidae increased due to deposited fine sediments from forest roads. Other studies have found that rapid recolonization and recovery of macroinvertebrates occurred following episodic sediment inputs (Debray and Lockwood, 1990).

EPA's Rapid Bioassessment Protocols (RBP) (Plafkin et al., 1989) are being used to assess regional and watershed-wide biological integrity. The RBP protocol for invertebrates uses quantitative kick samples in riffles which are composited into one sample. For specific project evaluation, quantitative methods using replicated samples may be needed to detect change. Kerans, Karr, and Ahlstedt (1992) compared qualitative and quantitative sampling methods. They found that replicated, quantitative sampling in riffle and pool habitats, using a variety of biological attributes, provided the strongest assessment of biological condition.

These findings suggest that the multiple metric approach used in the Rapid Bioassessment Protocols can be used successfully to detect change with some modification. To improve statistical power replicate samples should be collected rather than compositing the sample. Robison and Minshall (1992) found that quantitative samples using the modified Hess sampler were as fast as kick samples and were an improvement in providing additional information on the macroinvertebrate community.

The RBP protocols describe three levels of monitoring. RBP I and II are rapid qualitative evaluations of impairment using field identification to family level. These protocols are appropriate levels of biological monitoring for reconnaissance, but are not quantitative enough for the detection of trends over time needed for project evaluation.

RBP III is a more rigorous bioassessment technique which involves systematic field collection and lab analysis to the lowest taxonomic level (generally genus or species). Multiple metrics are used to assess the structure and function of the benthic macroinvertebrate community. The project site is compared to control stations or a set of regional reference sites which represent the biological potential. RBP protocols use a qualitative rating of habitat conditions to assist data interpretation. These rating systems can be used to supplement habitat characteristics that are not otherwise measured quantitatively.

Biological monitoring methods are currently undergoing rapid change. The methods outlined below are based on the Region 10 In-Stream Biological Monitoring Handbook (Hayslip, 1993). The handbook is a supplement to the Rapid Bioassessment Protocols (Plafkin et al., 1989) and discusses adaptations based on experience of State and Federal agencies, Universities, and others in the Pacific Northwest. These adaptations should generally be applicable to western streams; however, other regions are likewise evaluating and revising monitoring protocols. Monitoring coordinators with state water quality agencies or regional EPA offices should be contacted to obtain the most recent recommendations on protocols and availability of regional reference stations.

DATA COLLECTION

Habitat Description

The evaluation of habitat used in the Rapid Bioassessment Protocols is an integral part of data interpretation. The habitat assessment is used for evaluating both macroinvertebrate and fish protocols. The rating sheet is easy to complete in the field and provides a qualitative but comprehensive habitat evaluation. These habitat elements can be measured quantitatively as described in previous protocols - Stream Channel Morphology, Streambank Stability, Substrate Fine Sediment, Pool Quality annd Streamside Vegetation.

EPA Region X has modified the physical habitat assessment for application to streams in the Northwest (Hayslip, 1993). A separate assessment procedure has been developed for high gradient (riffle/run prevalence) and low gradient (glide/pool prevalence) streams. The parameters for high gradient streams are shown in Table 6.14 as an example. A copy of the Region X Handbook (Hayslip 1993) can be obtained to view the rating system.

Table 6.14. Physical habitat structure parameters for high gradient streams (Hayslip, 1993)

Primary Parameters:

1. Bottom substrate - percent fines
2. Instream cover (fish)
3. Embeddedness (riffle)
4. Velocity/depth

Secondary Parameters:

5. Channel shape (wetted channel)
6. Pool/riffle ratio
7. Width to depth ratio (using wetted width)

Tertiary Parameters:

8. Bank vegetation protection
9. Lower bank stability
10. Disruptive pressures (on streambank, immediately adjacent to stream)
11. Zone of influence - width of riparian vegetation zone.

FIELD AND LABORATORY PROCEDURES

A. Survey design

Survey design will depend on objectives, site characteristics, project treatment schedule and duration, and availability of reference stations. Discussion of biomonitoring survey design and statistical considerations are contained in Resh and McElravy, page 159-194 (1993) and the EPA macroinvertebrate methods manual (EPA, 1990). The Bioassessment Issue Papers (EA Engineeering, 1991) provide a useful discussion of habitat selection, subsampling, seasonality, and use of habitat assessment and regional reference sites.

1. Before-After/Control Site-Impact Site. This is a basic study design that incorporates sampling the project site and a control site or reference stream before and after the project. Where feasible, a local reference site should be sampled with the same methods and frequency as the project site. Where adequate local reference sites are not available, the data should be compared to regional reference conditions.

2. Sampling frequency. Macroinvertebrate populations vary seasonally due to natural life cycles and in response to environmental change such as temperature and streamflow. Sampling on a seasonal basis is often recommended to identify these cycles, but this may be cost prohibitive. For single season sampling, the period from July-October is recommended (Hayslip, 1993).

B. Field Procedures

1. Habitat selection. RBP III focuses on the riffle/run habitat type because it is the most productive habitat available in stream systems and includes many sensitive species (Plafkin et al., 1989). Other investigators recommend stratification of stream sampling into riffle and pool habitats (Kerans, Karr, and Ahlstedt, 1992; EPA, 1993). Riffle/run habitats should be selected at a minimum to standardize collection methods and assure comparison between sites.

2. Number of replicates. Composite samples of multiple kick samples are used in the Rapid Bioassessment Protocols to characterize biological condition. For statistical comparison of project and reference stations, individual replicate samples should be collected. Three to five replicate samples are often used for quantitative studies (Resh and McElravy, 1993). The Idaho Protocol document suggests a minimum of three replicates (Clark and Maret, 1993).

3. Sampling device. Kick samples used in the Rapid Bioassessment Protocols provide a semi-quantitative sample. Surber or Hess samples are used to collect replicate quantitative samples. Recommended mesh size for samplers is usually 500 micron (Clark and Maret, 1993; Mulvey, Caton and Hafele, 1992). Detailed descriptions of these samplers and their operation are provided in Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters (EPA, 1990).

4. Subsampling. Rapid Bioassessment Protocols recommend a subsample containing a minimum of 100 organisms. The EPA Environmental Monitoring and Assessment Program recommends that in minimum of 300 organisms be counted (EPA, 1993). Field subsampling provides several advantages. Organisms are easier to see and sort when they are alive, specimens are preserved in better condition when presorted from debris, and presorting is less time-consuming and therefore cost-effective (Hayslip, 1993).

Subsampling consists of evenly distributing the sample in a gridded pan with a light-colored bottom. As grids are randomly selected, all organisms within those grids are removed, until a minimum of 100 organisms have been selected. Once a grid is selected, the grid is completely picked to avoid bias in selecting only the most obvious specimens.

Caton (1991) has developed an improved method of sub-sampling using a gridded sieve. The sieve provides a distinct isolation of random sub-samples. The selected sub-sample from the grid is placed in a separate pan from which the sample can be easily picked.

DATA ANALYSIS

1. Taxonomic identification. All macroinvertebrates in the sub-sample are identified to the lowest possible taxonomic level in the laboratory, generally genus and species. Because of the diversity of species in benthic samples, it is best to have the identifications completed by an experienced taxonomist. State monitoring coordinators should be contacted for a list of qualified specialists.

2. Metrics. The Rapid Bioassessment Protocols describe (Plafkin et al., 1989) the use of multiple community metrics to evaluate biological condition. Benthic community health is described by a variety of metrics which measure community structure, community balance, and functional feeding groups. Each metric is assigned a score based on the percent similarity to the reference station. Individual metric scores are totaled and compared to the total metric score for the reference station to provide an overall evaluation of biological condition.

Eight community metrics (Table 6.15) were originally included in the 1989 RBP protocols document. These metrics are being tested for their utility and application in different regions. With the current effort at testing and evaluation of metrics, the use of any set of metrics should be used cautiously.

Table 6.15. Metrics recommended in the Rapid Bioassessment Protocols (Plafkin et al., 1989)

- Structure Metrics
  - Taxa richness
  - Ephemeroptera/Plecoptera/Trichoptera index (EPT index)
  - Community similarity indices
- Community Balance Metrics
  - Hilsenhoff biotic index (modified)
  - Percent contribution of dominant taxon
  - Ratio of EPT and Chironomid abundance
- Functional Feeding Group Metrics
  - Ratio of scrapers/filtering collectors
  - Ratio of shredders/total

Barbour et al. (1992) evaluated the RBP and other metrics for redundancy and variability among reference streams using data from Kentucky, Oregon, and Colorado. Since the data contained several data sets from western streams, the conclusions should be useful. Of the eight original RBP metrics they recommended retaining four of the RBP metrics and recommended modifications of two others. Taxa Richness and EPT Index were considered useful measures of community structure. The EPT Index is a relative measure of the presence of pollution-sensitive macroinvertebrate groups and was recommended for most assessments. The Hilsenhoff Biotic Index was retained without modification as a measure of community balance. Shredders/Total exhibited high variability, but was recommended to be retained based on results of other analysis. The metric Ratio of Scrapers/Filterers was modified by adjusting it to a percentage. They suggested EPT/Chironomidae be replaced by another metric such as Hydropyschidae/Trichoptera. The Pinkham and Pearson index was recommended as the most appropriate measure of community similarity. A revised list of metrics based on this analysis is shown in Table 6.16.

Metrics will continue to be tested for application in different regions and to be sensitive to various environmental stressors. The investigator should contact state monitoring coordinators or EPA regional offices to stay current with recommendations for macroinvertebrate community analysis.

Table 6.16. Metrics proposed for macroinvertebrate community analysis (Barbour et al., 1992)

Metric	Description
	Community Structure Metrics
Taxa Richness	Total number of distinct taxa. Generally richness is increased with improved water quality and substrate diversity.
EPT Taxa Index	Total number of distinct taxa within the generally pollution-sensitive insect orders – Ephemeroptera, Plecoptera, and Trichoptera.
Pinkham-Pearson index	This is a community similarity index which incorporates abundance and composition information.
Quantitative Similarity Index	The index compares two communities in terms of presence or absence of taxa, also taking relative abundance into accounts.
	Community Balance Metrics
Hilsenhoff Biotic Index (modified)	The HBI index summaries pollution tolerance to organic and sediment pollution. Pollution tolerance values range from 0 to 10 with 0 indicating the least tolerance (Hilsenhoff, 1987). Modified to include nonarthropod taxa (Plafkin et al., 1989).
Percent Dominant Taxa	A simple measure of redundancy and evenness. Assumes that an abundance of a single taxon reflects an impaired community.
Dominants in common	Dominants in common for five most abundant taxa. Measures the similarity to reference station based on five most abundant taxa.
% Hydropyschidae/Trichoptera	Measures the relative contribution of the generally mild pollution tollerant family, Hydropsychidae, to total Trichoptera.
	Functional Feeding Groups
% Scrapers/(Scrapers + Filterers)	Percentage of invertebrates classified as scrapers to total of scrapers plus filterers. Reflects the balance of the riffle/run community food base.
% Shredders/Total	Percentage of shredder abundance to the combined total number of organisms. Measures the relative abundance of shredders which are sensitive to riparian zone impacts.
Quantitative Similarity Index for Functional Feeding Groups	Compares two communities in terms of presence or absence of functional feeding groups.

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K. BIOMONITORING: FISH COMMUNITY

INTRODUCTION

Water quality and habitat parameters assess the cause and effect linkage between grazing and its effect on fish as a beneficial use. Monitoring the fish community provides a direct measure of beneficial use support.

Fish communities are good indicators of long-term effects and broad habitat conditions because they are relatively long-lived and mobile (Karr et al., 1986). These characteristics also present some challenges for using fish in project evaluation. Stream fish use different habitats at various life stages and may migrate long distances. The fish population at any location is therefore influenced by activities throughout the stream length. In comparison to macroinvertebrates, fish communities are affected directly by fishing pressure and fishery management activities and may recover more slowly in response to water quality improvements.

Fisheries monitoring is often aimed at the population level. Game fish populations are evaluated in terms of relative abundance, weight-length relationships, condition, age, and growth. Assessment of biological integrity is directed more broadly at aquatic community structure and function (EPA, 1990) of the fish community including both game and non-game species. EPA Rapid Bioassessment Protocol V (Plafkin et al., 1989) assesses stream fish communities using the ecological approach described by the Index of Biotic Integrity (IBI) (Karr 1981, Karr et al., 1986). The IBI compares observed attributes (metrics) of the fish community with the attributes expected for a similar reference stream. The metrics address species richness and composition, trophic composition, and fish abundance and condition.

The IBI was developed primarily for eastern and mid-western streams, so use of this method requires adaptation to the western fish fauna. The ecological requirements of fish species need to be evaluated in relation to trophic guild and tolerance to pollution. Professional judgement of an aquatic ecologist or fish biologist familiar with IBI is needed to choose the most appropriate population or community element that is representative of each metric in setting the scoring criteria (Plafkin et al., 1989). Cold water streams are characterized by a depauperate fish assemblage which requires modification of the IBI. Adaption of the IBI to cold water streams is in a development phase, and no concensus list of metrics or scoring criteria is currently available.

Given the current status of IBI for western streams, no definitive recommendation can be made for its use in assessing grazing impacts at this time. Some suggested modifications to IBI metrics which are applicable to western streams are summarized below. Individual metrics, combined with traditional fish population techniques, may be used to gain information on the status of the fish community. Certainly, information on the fish community will add to the weight-of-evidence approach in evaluating water quality change. As with the macroinvertebrate methods, monitoring coordinators with state water quality agencies should be contacted for recent developments in bioassessment protocols applicable in the ecoregion.

OVERVIEW

Improper grazing affects cold water fisheries by increases in stream temperature, reduction of vegetative cover and streambank stability, increase of fine sediment in spawning and rearing habitat, and reduction of fish food organisms (see Section II). Changes to stream and riparian habitats are well documented; however, studies which measured fish populations are less conclusive. Fish population response was often inconclusive in studies reviewed by Platts (1991) due to the high variation in fish population estimates, lack of pre-grazing data, or lack of comparable controls.

With Rapid Bioassessment Protocols (RBP V), the fish community is evaluated by collecting a representative sample of all fish species and size classes in the designated stream reach. Generally a single pass using electrofishing gear is used to evaluate community composition. For fish population estimates a multiple pass method using block nets is required. Snorkeling may be used to collect this information where sensitive or endangered species occur. Species identification and enumeration are completed in the field. A trained fishery biologist should be involved in the project to assist in gear selection and species identification.

DATA COLLECTION

1. Habitat Description. The RBP Protocol uses the same habitat assessment for fish as for macroinvertebrates (See Table 6.14). The habitat elements can be measured quantitatively as described in previous protocols - Stream Channel Morphology, Streambank Stability, Substrate Fine Sediment, Pool Quality and Streamside Vegetation.

2. Site Selection. Monitoring sites should include habitat types representative of the reach and should encompass several riffle-pool sequences. Generally, the monitoring sites (described in Section IV) established for the other riparian parameters can be used. A sufficient reach length is needed to obtain a representative sample. Recommendations for appropriate reach length vary; 20 times the bankfull width with a minimum of 100 meters (Chandler, Maret and Zaroban, 1993), thirty to forty times the bankfull width with a minimum of 200 meters, and 300 meters (Angermeier and Karr, 1986). Reach lengths and habitat units should be comparable to reference locations to facilitate data analysis.

Monitoring for fish community metrics is generally completed during the stable low flow period in mid-summer. This period generally avoids spawning migrations and seasonal movement of fish. However, the sample period needs to be adjusted to the life history of target species in the watershed and may vary between resident and anadromous species.

3. Sampling methods. Fish collection needs to be coordinated closely with the state fish and game agency. State agencies require collection permits which usually specify gear types and sampling periods. Although electrofishing is a standard procedure, it may not be allowed in waters which contain threatened or endangered species. In these waters enumeration of fish species and lengths can be obtained by snorkeling techniques. Electrofishing methods are described in EPA Fish Field and Laboratory Methods (EPA, 1993).

Level of effort in the field depends on the data analyis to be performed. Single pass removal using electrofishing is sufficient to obtain a representative sample of relative abundance for calculating IBI metrics. The three pass removal method is a minimum effort if fish population estimates are also desired (Zippin, 1956).

Underwater visual estimates using snorkel techniques are used to count fish and estimate lengths when fish can not be collected directly (Griffith, 1981; Helfman, 1983). In small streams an observer moves slowly upstream and searches hiding cover created by organic debris, undercut banks, boulders, pools, etc. for fish. In larger streams, pairs of observers may be needed. In streams too deep for upstream snorkeling, teams of observers float down a habitat unit and count fish in their designated lane.

4. Sample processing. All fish captured are counted and identified to species in the field. Additional information on selected fish species may be obtained by recording total length and weight. Young of the year age classes should be enumerated since this provides important information on reproductive success.

C. Data Analysis

The IBI uses twelve biological metrics to assess integrity based on the fish community's taxonomic and trophic composition and the abundance and condition of fish (Karr et al., 1986). Hughes and Gammon (1987) modified five of the original twelve metrics in applying the IBI to a large western river, the Williamette River in Oregon. These adjustments are useful in evaluations of large rivers, but may not be applicable to small rangeland streams. An alternative IBI for fish communities with low species richness typical of the Northwest has been proposed (Hayslip, 1993), but this alternative has not been evaluated.

Robinson and Minshall (1992) tested twenty metrics for application in small streams in two ecoregions in southern Idaho, the Snake River Plain and the Northern Basin and Range. Stream sites were established in upland and lowland areas and designated as relatively unimpacted and impacted. Six metrics were found useful in detecting a shift from relatively intolerant salmonid-based systems to tolerant non-salmonid communities. These metrics include Number of Salmonidae Taxa, Number of Tolerant Taxa, Percent Salmonidae, Salmonidae

Biomass, Tolerant Species Density, and Salmonidae Condition Index.

The State of Idaho has incorporated these six metrics into their biotic assessment protocol for fish (Maret, Chandler and Zaroban, 1993). The protocol identifies trophic guilds, pollution tolerance, and origin status (native or introduced) for species in the state. The proposed list of metrics is listed in Table 6.17. These metrics have not been thoroughly evaluated for use in a biotic index, but, they do provide a starting point for consideration of metrics that may be useful in western streams.

Monitoring the fish community provides valuable information for evaluation of biotic integrity. Data can be collected fairly easily in the field under the direction of an experienced fishery biologist. However, it is important to analyze the fish response carefully in the context of multiple environmental and biological factors in the watershed to avoid erroneous conclusions about grazing impacts.

Table 6.17. Fish metrics proposed for evaluating stream health in Idaho streams (Maret, Chandler, and Zaroban, 1993). Those marked by an (*) are recommended to assess the biotic integrity of cold water streams.

Metric	Description
	Species Richness and Composition
Total number of species	Total number of fish species will theoretically decrease with increasing degradation. Number of species may increase in degraded waters as habitat becomes available for tolerant introduced species.
* Number of native species	Total number of native species decreases in degraded waters.
Number of introduced species	Indtroduced species often occur more frequently in degraded waters.
* Number of salmonid species	Number of salmonid species decreases in degraded waters.
* Number of intolerant species	Intolerant species are sensitive to pollution and decrease in degraded waters.
% Introduced species	Percent of introduced species in relation to the total number of species collected. As degradation occurs native species are often replaced by introduced species.
* Jaccard Coefficient	Measures the degree of similarity in species composition between two stations. Described in Plafkin et al. (1989).
	Trophic Composition
% Carnivores	Number of top carnivores in relation to the total number of species in the sample. Number of carnivores decreases in degraded waters.
% Omnivores	Number of omnivores in relation to the total number of species in the sample. Omnivores increase in the fish community in degraded waters.
* % Insectivores	Number of insectivores in relation to the total number of species in the sample. Insectivores generally decrease in the fish community in degraded waters.

Table 6.17. Page 2

	Abundance and Density
* % Salmonids	Proportion of the total number of fish counted that are salmonids. This metric will decrease with increasing degradation.
Density (#/ha)	Total density in the habitat sampled. Interpreted separately for tolerant and intolerant species.
* Total fish biomass (Kg/ha)	Total fish biomass in the habitat sampled. Interpreted separately for tolerant and intolerant species.
* Salmonid density (#/ha)	Number of salmonids per unit of area. Number of salmonids decreases in degraded waters.
* Salmonid biomass (Kg/ha)	Salmonid biomass per unit of habitat sampled.
Fish per unit of effort (#/min.)	Fish captured per unit of time sampled. A relative measure of abundance.
	Condition and Age Structure
* % YOY salmonids	Proportion of Young of the Year salmonids in the sample. This metric provides information on salmonid spawning success.
% Anomolies	Proportion of fish in the sample with external lesions, tumors, parasites and fin erosion. Percent anomolies increases in polluted waters.
Salmonid condition factor	Comparison of weight and length in an individual, $(w/1^3)$ *10,000 where w is weight in grams, and 1 is length in milameter Condition factor decreases in degraded waters in comparison to reference stations.

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GLOSSARY

Accuracy. The degree of agreement between the measured value and the true value.

Aggradation. Deposition in one place of material eroded from another. Aggradation raises the elevation of streambeds, flood plains, and the bottoms of other water bodies.

Animal Unit Month. Amount of feed or forage required by one animal-unit grazing on a pasture for one month. An animal-unit is one mature (454-kg) cow or the equivalent of other animals, based on an average daily forage consumption of 12 kg of dry matter.

Attribute. A single element (velocity, depth, cover, etc.) of the habitat or environment in which a fish or other aquatic species or population may live or occur.

Bankfull channel. The bankfull channel contains the momentary maximum peak flow; one which occurs several days in a year and is often related to the 1.5 year recurrence interval discharge.

Bankfull width. The cross-section width of the bankfull channel, typically identified as the upper limit of stream channel scour below which perennial vegetation does not occur.

Beneficial uses. Uses of water which typically include aquatic life (warm water and cold water biota), recreation (primary and secondary contact), water supply (agricultural, domestic, and industrial), wildlife habitat, and aesthetics. Designated uses are those uses defined in state water quality standards for each waterbody.

Bias. Bias is the reciprocal of accuracy; bias measures the average departure of estimates from the true value.

Biocriteria. Numerical values or narrative expressions in water quality standards that describe the biological integrity of aquatic communities.

Cobble embeddedness. The degree to which cobbles are surrounded or covered by fine sediment (sand or silt), usually expressed as a percentage.

Community type. An abstract grouping of all communities (stands) based on floristic and structural similarities in both overstory and undergrouth layers.

Confinement. The relationship of a channel to the valley walls or terrace. It describes how restrictive the valley's walls are in limiting the channel's lateral movement (meandering).

Cross-channel transect. A permanently marked linear plot across a stream channel that is perpendicular to the thalweg of a stream. The transect is marked on either side of the stream and above the bankfull level.

Desired Future Condition (DFC). The resource condition or site-specific objectives, based on the resource values wanted. The DFC must be based on the potential of the site to produce that resource value or condition.

Dissolved ortho-phosphate. Ortho-phosphate as P determined from a field-filtered sample; considered a measure of the biologically available phosphorus.

Ecological status. The degree of similarity or comparison between current vegetation and the potential natural community (PNC) for the site.

Ecoregion. Regional ecosystems desribed by causal characteristics including climate, mineral availability (sois and geology), vegetation, and physiography.

Ecological succession or plant succession. The process of vegetational development in which plant communities progress from a lower to a higher ecological status.

Entrenchment. The relation of the channel to the valley flat or floodplain, i.e., downcutting, incising.

Eutrophication. The process of over-fertilization of a body of water by nutrients that produce more organic matter than the self-purification processes can overcome.

Fecal coliform. Bacteria as defined above with the exception of using an elevated incubation temperature of 44.5°C which separates bacteria of fecal origin (primarily *E. coli*) from bacteria derived from non-fecal sources.

Fecal streptococcus. Group of species of the genus *Streptocccus*, such as *S. faecalis*, *S. faecium*, *S. avium*, *S. bovis*, *S. eqiinus*, and *S. gallinarum*. All give a positive reaction with Lancefield's Group D antisera.

Forage. The part of the vegetation that is available and acceptable for animal consumption, usually herbaceous and shrub species.

Goal. The overall aim or endpoint of the project.

Green Line. The first perennial vegetation above the stable low water line of a stream or water body.

Habitat attribute. An element used to describe a habitat unit, i.e. length, bankfull depth, substrate size, streambank conditions.

Habitat unit. A run, riffle, pool, or glide along a stream.

Hydric soil. A soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation.

Intermontane. Stream within a forested mountainous area.

Left bank. The left hand side of the stream looking downstream.

Low flow channel. This is the channel below the water surface level during the annual period of low flow (usually late summer). The low flow level in the cross section is often the water surface at the time of sampling in mid to late summer. The flow at this time is often low enough to expose gravel/sand bars. The low flow channel is sometimes evidenced by a distinct channel impression between the inner-berm bars.

Macroinvertebrates. Refers to organisms that inhabit the bottom substrates (sediments, debris, logs, macrophytes, etc.) of freshwater habitats for at least part of their life cycle and generally are retained by mesh sizes between 200-500 microns.

Monitoring site. A site within a stream reach selected to represent the sub-area for collecting detailed water quality data (i.e., vegetation, water chemistry, temperature, dissolved oxygen).

Overhanging vegetation. Live plants (graminoids, forbs, shrubs, and trees) that extend over the stream at least 12 inches from the bank and within 12 inches of the water's surface at stable low flow.

Objective. A subset of project goals. Objectives are expressed in quantitative terms.

Parameter. Any constant, with variable values, used as a referent for determining other variables. For purposes of this report, parameter refers to a feature of the ecosystem which can be measured or evaluated.

Plant Succession. The process of vegetational development in which plant communities progress from a lower to a higher ecological status.

Pool. Pools as defined in the literature (Platts, Megahan, and Minshall, 1983; and Bisson et al., 1982), have these characteristics:

- An area of the stream that has reduced water velocity.
- Water depth is deeper than surrounding areas.
- The water surface gradient at low flow is often near zero.
- The bed is often concave in shape and forms a depression in the profile of the stream's thalweg.
- Pools are formed by features of the stream that cause local deepening of the channel. This results from lateral constrictions in flow or by sharp drops in the water surface profile.

Potential Natural Community (PNC). The combination of plant species that would result if ecological succession were completed without interruption.

Precision. Denoted the agreement between the numerical values of two or more measurements on the same homogeneous sample made under the same conditions. The term is used to describe the reproducibility of the measurement or method.

Primary forage. Vegetation preferred by grazing animals.

Primary succession. The initial establishment of vegetation on bare surfaces not previously vegetated, such as a recently deposited point bar.

Protocol. A system of methods. For the purpose of this report, a protocol is a defined procedure or procedures for measuring change in an ecosystem parameter.

Right bank. The right hand side of the stream looking downstream.

Resource Value Rating (RVR). The degree of similarity of the existing resource conditions (vegetation, habitat, streambanks, etc.) to the future desired condition.

Representative reach. A portion of a stream that contains characteristics similar to a larger segment that it represents.

Riparian area. Geographically delineable area with distinctive resource values and characteristics that are comprised of the aquatic and riparian ecosystems.

Riverine. Relating to or resembling a river or stream.

Salmonid. Any species of fish from the family Salmonidae.

Secondary succession. The sequence or progression of plant communities from a disturbed state or condition (e.g. fire, livestock grazing, flooding, ice, drought) toward the potential natural community.

Sinuosity. The ratio of the channel length to the valley length.

Stratification or stratified stream segment. A portion of a stream that is relatively homogeneous based on geomorphology, stream flow, geology, and sinuosity. It is frequently bounded by significant tributaries, diversions, reservoirs, etc.

Streambank cover. Banks are covered if they show any of the following features:

- Perennial vegetation ground cover is greater than 50%.
- Roots of vegetation cover more than 50% of the bank (deep rooted plants such as willows and sedges provide such root cover).
- At least 50% of the bank surfaces are protected by rocks of cobble size or larger.
- At least 50% of the bank surfaces are protected by logs of 4 inch diameter or larger.

Streambank stability. Banks are stable if they do not show indications of any of the following features (see Figure 6.6):

- BREAKDOWN (obvious blocks of bank broken away and lying adjacent to the bank breakage).
- SLUMPING or FALSE bank (bank has obviously slipped down, cracks may or may not be obvious, but the slump feature is obvious).
- FRACTURE (a crack is visibly obvious on the bank indicating that the block of bank is about to slump or move into the stream).
- VERTICAL AND ERODING (The bank is mostly uncovered as defined below and the bank angle is steeper than 80 degrees from the horizontal).

Stream meander cycle. One full cycle of typical hydraulic (habitat) units (i.e., one pool and one riffle/glide). A stream meander cycle is usually over a stream distance that is 5 to 7 times the bankfull width.

Stream order. A system of ranking a stream and its tributaries from the headwaters to its mouth. The ranking is expressed as a number from 1 to 7.

Stream reach. A designated section of a stream at which monitoring is conducted and hydrologic and/or fishery predictions are made.

Stream segment. A distance of stream that is at least 1 stream meander cycle in length.

Stream type. A stream classification system based on a combination of stream entrenchment, sinuosity, gradient, width/depth ratio, confinement, and soil/land/form.

Substrate embeddedness. See cobble embeddedness.

Thalweg. A line connecting the deepest parts of a stream.

Thermal input. The amount of solar energy (in BTU's/Ft^2/day) striking the water surface.

Total coliform. All aerobic and facultative anaerobic, gram-negative, nonspore-forming, rod-shaped bacteria that ferment lactose with gas and acid formation within 24 h. at 35°C. Includes *Escherichia coli*, *Klebsiella*, *Enterobacter*, and others.

Total Nitrite plus Nitrate. The inorganic oxidized form of nitrogen, NO_2 plus NO_3, determined from the whole sample.

Total Kjeldahl Nitrogen (TKN). A measure of organic nitrogen defined by the analytical method; includes nitrogen bound in organic compounds and ammonia.

Total phosphorus. Phosphorus as P determined by colorimetry after digestion of organic matter in an unfiltered sample.

Undercut bank. An undercut bank is defined as follows: that bank which has been cut by the stream so that a protrusion of the upper portion of the bank overhangs the water surface. The water level does not influence this reading.

Utilization. The amount (expressed as a percentage or level, light, moderate, heavy, or severe) of vegetation removed by a grazing animal, including but not limited to elk, deer, moose, antelope, cattle, sheep, horses, and goats.

Vegetative canopy cover. The area of the sky over the stream channel bracketed by vegetation (Platts et al; 1987).

Vegetative canopy density. The amount of sky (or sunlight) over the stream channel blocked by vegetation (Platts et al., 1987).

Width to depth ratio. The ratio of water width to average water depth.

Witness marker. A steel post, marked fence post or tree, mound of rocks, or other appropriate device used to monument for relocating permanent photo points or cross-channel transects.

Woody species. Plant species classified as shrubs or trees.

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APPENDIX A

INITIAL EVALUATION

1. Basic Information Data Sheet
2. Instructions for the Basic Information Data Sheet
3. Review of Existing Data
4. Instructions for Existing Data Listing

1. BASIC INFORMATION DATA SHEET

Stream Name: ______________________________ Date: ______________

Sub-Area: __________ EPA No. ____________________

Maps: ____________________________ Photos: ____________________

Information Collected by: __________________ Agency: ____________________

Geomorphic Setting:

Stream Order: ______ Gradient: ______ Valley Bottom Type: _____ Aspect: _______

Elevation: Upper ____________ Lower: ____________ Entrenchment: ____________

Sinuosity: ________ Dominant Substrate: __________ Stream Type (Rosgen): ________

Size: Length ________________ (Miles or Feet) Area __________________ (Acres)

Landform: ____

Geology and Soils:

Geologic Parent Material: ____

Soil Mapping Units:

Mapping Unit Nos.: Soil Family Name:

______________ ____

______________ ____

Dominant Vegetation:

____ Conifer ____ Deciduous ____ Shrub ____ Herbaceous/Graminoid ____ Non-vegetated

Dominant Land Use(s): ____

____

Comments:

2. INSTRUCTIONS FOR THE BASIC INFORMATION DATA SHEET

Stream Name: Name of the stream or stream segment described.

Date: Date information collected.

EPA No.: EPA Stream Reach Number based hydrologic units.

Stream Segment Length: The length in miles of the stream segment described on the data sheet.

Area Size: Riparian area size associated with the stream reach.

Quad(s): List the U.S.G.S. topographic maps used.

Aerial Photo(s): List the aerial photos used.

Information Collected By: List the individual(S) collecting the data.

Agency: List agency responsible for data.

Stream Order: The stream order for the reach described.

Gradient: The gradient of the stream segment described, obtain the information from topographic maps.

Valley Bottom Type: The valley bottom type described in Appendix B.

Aspect: The general aspect of the stream reach described.

Elevation: The upper and lower elevation of the stream reach.

Entrenchment: The degree to which the stream is confined to the stream channel, see Appendix B.

Sinuosity: The stream channel length divided by the valley bottom length.

Dominant Substrate: The stream bed substrate inferred from existing information, e.g. soil survey, stream surveys.

Stream Type: The Rosgen stream type as described in Appendix B. Usually must be completed after the Reconnaissance level inventory.

Parent Material: List the major parent materials that effect the stream.

Landform: Provide the land form from the soil survey or describe the land form.

Soil Mapping Units: List the dominant soil mapping unit for the riparian areas.

Soil Family Name: List the name of the soil family.

Dominant Vegetation: Mark the apparent dominant vegetation along the stream.

Dominant Land Use: Describe the major land use activities affecting water quality.

3. REVIEW OF EXISTING DATA

Stream Name: ______________________ EPA Stream Reach No. __________

Compiled by: ______________________ Date: __________

Maps and Aerial Photos Available:

Name	Type & Scale

Water Quality (Chemical & Physical):

Report Name	Source	Location

Fish and Macroinvertebrates:

Soils and Vegetation:

Stream Flow and Other Stream Parameters:

Other

____

____

____

____

4. INSTRUCTIONS FOR EXISTING DATA LISTING

Stream Name: Provide the name of the stream segment basic information listed.

EPA No.: EPA Stream Reach Number based on the hydrologic region.

Compiled by: Provide the name(s) of the individuals compiling the data.

Date: Date of data compilation.

Type: List the type of map and/or aerial photos, i.e. orthophoto, topographic.

Scale: Provide the scale of the map or aerial photo, i.e. 1" = 1 mile, 1:20,000.

Source: List the agency that produced the report.

Location: List the Location of the report or data.

Existing resource information is important to assist in assessing water quality. It can save duplication of effort, provide baseline data, and guide future inventory and monitoring efforts. This form provides a listing of various types of existing inventory and monitoring data, source of the information, and the location of the data.

APPENDIX B

RECONNAISSANCE LEVEL - CLASSIFICATION

1. Valley Bottom Type
2. Stream Channel Classification Definitions
3. Summary of delineative criteria for broad-level classification.
4. Longitudinal, cross-sectional and plan views of major stream types.
5. Meander width ratio (belt width/bankful width) by stream type categories.
6. Illustrative guide showing cross-sectional configuration, composition, and delineative criteria of major stream types.
7. Key to classification of natural rivers.
8. Examples and calculations of channel entrenchment.
9. Management interpretations of various stream types.
10. Definitions of aquatic community habitat types.
11. Suggested riparian plant identification keys and riparian community type guides.

Note: Items 2 through 9 are taken directly from the most recent stream channel classification by David Rosgen (1993). The reader is referred to this publication for use of the stream classification.

Rosgen, D.L. 1993. A classification of natural rivers. [In Review] Catena, Germany.

1. VALLEY BOTTOM TYPE *

VALLEY FORM:

U-Shape	1000
V-Shape	2000
Trough-Like	3000
Flat Bottom	4000
Box Canyon	5000

VALLEY BOTTOM GRADIENT:

Very Low	< 2%	100
Low	2 - 4%	200
Moderate	>4 - 6%	300
High	>6 - 8%	400
Very High	>8%	500

VALLEY BOTTOM WIDTH:

Very Narrow	< 10 m	10
Narrow	10 - 30 m	20
Moderate	30 - 100 m	30
Broad	100 - 300 m	40
Very Broad	>300 m	50

VALLEY SIDE SLOPES:

Low	< 30%	1
Moderate	30 - 60%	2
Steep	> 60%	3

* From USDA Forest Service (1992)

Example:

Flat Bottom (4000), Low Gradient (200), Narrow Valley (20), and Low Side Slopes (1) =

Typical Code 4221

2. STREAM CHANNEL CLASSIFICATION DEFINITIONS

Entrenchment--the ratio of the flood zone width, at two times the bankfull depth, divided by the bankfull width. Measurements are made on site.

Gradient--the percent slope of the water surface. Measurements may be made from topographic maps or on site.

Sinuosity--the stream channel length divided by the valley length. Measured from a topographic map or on site.

Width/Depth (W/D) Ratio--the bankfull width divided by the bankfull depth. Measurement is made on site.

Dominant substrate--the size of most of the bottom particles or material in a streambed. Substrate in the stream is estimated or measured using a Wolman pebble count. Measurements or estimates are made in the field.

Confinement--the amount of lateral movement a stream channel can make as a result of geologic structures such as valley walls or terraces.

Table 2. Summary of delineative criteria for broad-level classification.

Stream Type	General Description	Entrenchment Ratio	W/D Ratio	Sinuosity	Slope	Landform/Soils/Features
Aa+	Very steep, deeply entrenched ,debris transport streams.	<1.4	<12	1.0 to 1.1	>.10	Very high relief. Erosional, bedrock or depositional features; debris flow potential. Deeply entrenched streams. Vertical steps with/deep scour pools; waterfalls.
A	Steep, entrenched, cascading, step/pool streams. High energy/debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel.	<1.4	<12	1.0 to 1.2	.04 to .10	High relief. Erosional or depositional and bedrock forms. Entrenched and confined streams with cascading reaches. Frequently spaced, deep pools in associated step-pool bed morphology.
B	Moderately entrenched, moderate gradient, riffle dominated channel, with infrequently spaced pools. Very stable plan and profile. Stable banks.	1.4 to 2.2	>12	>1.2	.02 to .039	Moderate relief, colluvial deposition and/or residual soils. Moderate entrenchment and W/D ratio. Narrow, gently sloping valleys. Rapids predominate w/occasional pools.
C	Low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad,well defined floodplains	>2.2	>12	<1.4	<.02	Broad valleys w/terraces, in association with floodplains, alluvial soils. Slightly entrenched with well-defined meandering channel. Riffle-pool bed morphology.
D	Braided channel with longitudinal and transverse bars. Very wide channel with eroding banks.	n/a	>40	n/a	<.04	Broad valleys with alluvial and colluvial fans. Glacial debris and depositional features. Active lateral adjustment, w/abundance of sediment supply.
DA	Anastomosing (multiple channels) narrow and deep with expansive well vegetated floodplain and associated wetlands. Very gentle relief with highly variable sinuosities. stable streambanks.	>4.0	<40	variable	<.005	Broad, low-gradient valleys with fine alluvium and/or lacustrine soils. Anastomosed (multiple channel) geologic control creating fine deposition w/well-vegetated bars that are laterally stable with broad wetland floodplains.
E	Low gradient, meandering riffle/pool stream with low width/depth ratio and little deposition. Very efficient and stable. High meander width ratio.	>2.2	<12	>1.5	<.02	Broad valley/meadows. Alluvial materials with floodplain. Highly sinuous with stable, well vegetated banks. Riffle-pool morphology with very low width/depth ratio.
F	Entrenched meandering riffle/pool channel on low gradients with high width/depth ratio.	<1.4	<12	>1.4	<.02	Entrenched in highly weathered material. Gentle gradients, with a high W/D ratio. Meandering, laterally unstable with high bank-erosion rates. Riffle-pool morphology.
G	Entrenched "gulley" step/pool and low width/depth ratio on moderate gradients.	<1.4	<12	>1.2	.02 to .039	Gulley, step-pool morphology w/moderate slopes and low W/D ratio. Narrow valleys, or deeply incised in alluvial or colluvial materials; i.e., fans or deltas. Unstable, with grade control problems and high bank erosion rates.

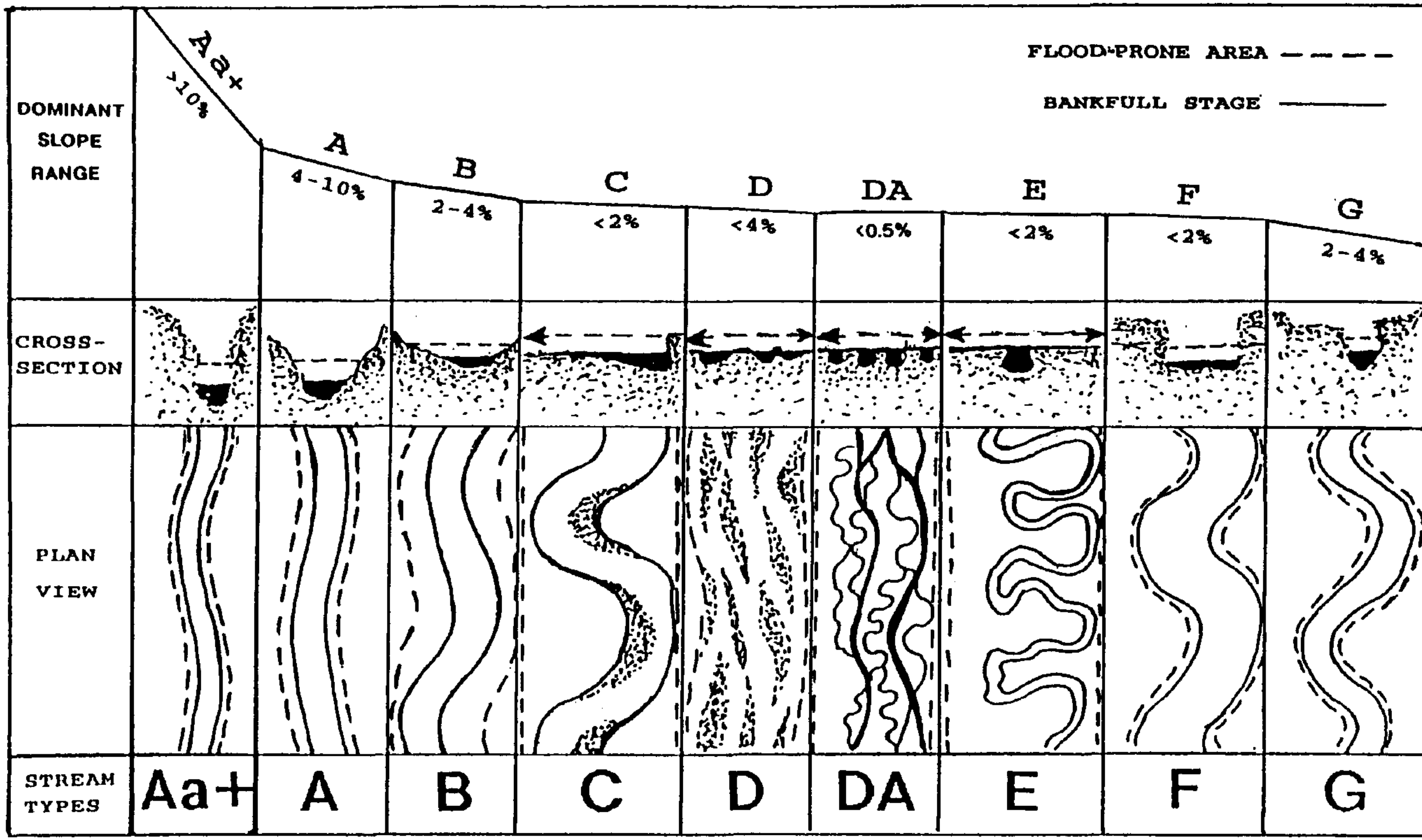


Figure 1. Longitudinal, cross-sectional and plan views of major stream types.

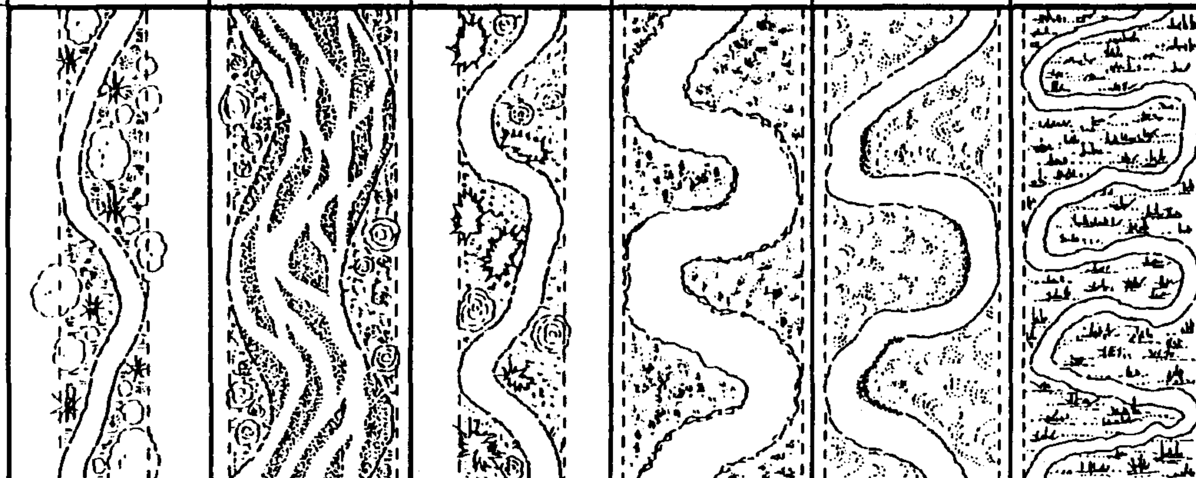
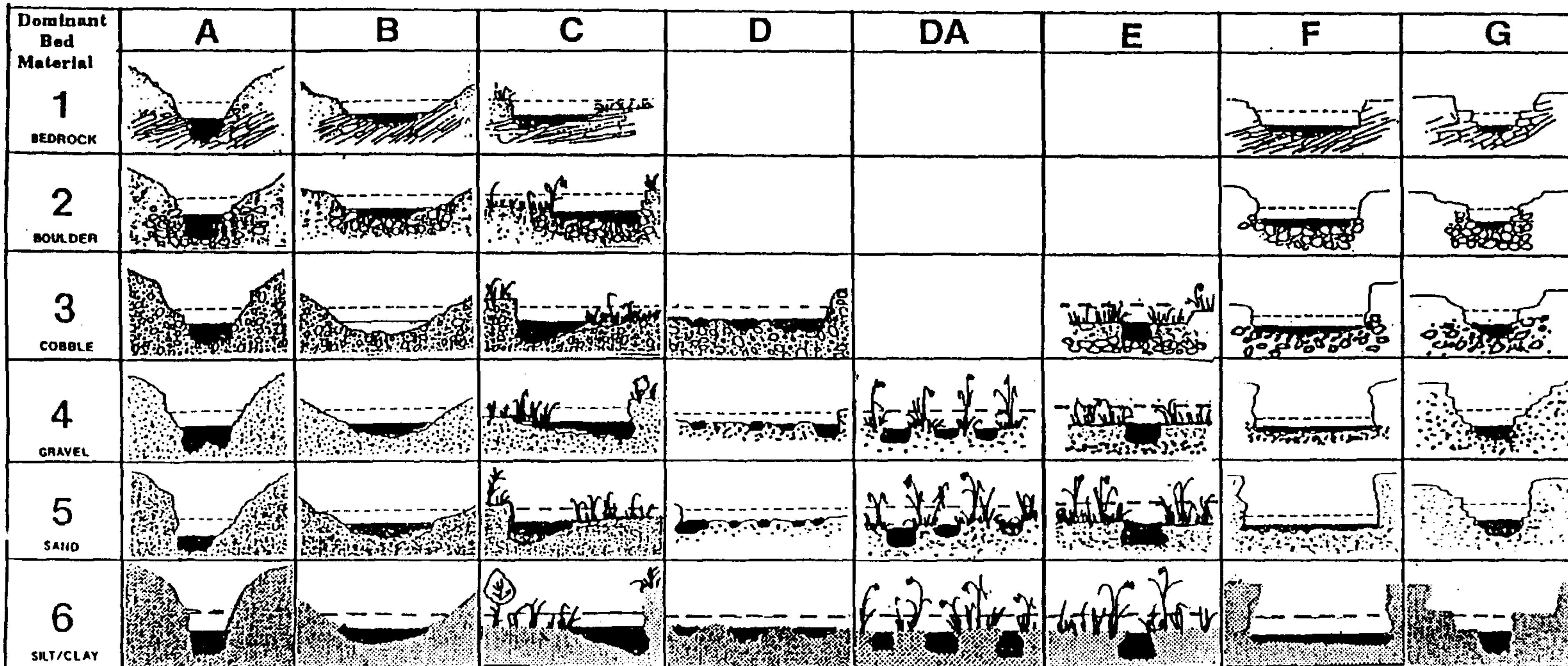
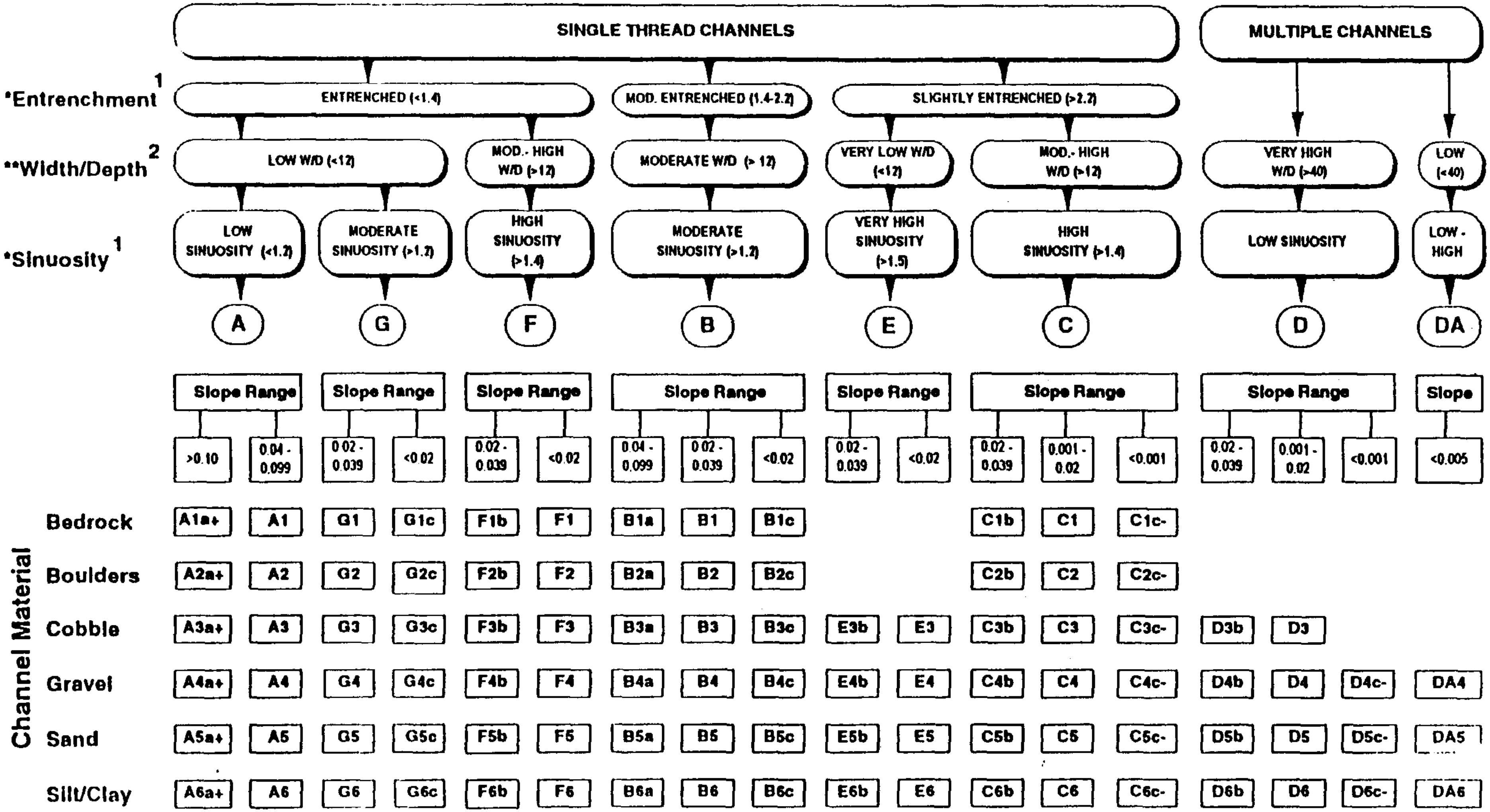
STREAM TYPE	A	D	B & G	F	C	E
PLAN VIEW						
CROSS-SECTION VIEW						
AVERAGE VALUES	1.5	1.1	3.7	5.3	11.4	24.2
RANGE	1–3	1–2	2–8	2–10	4–20	20–40

Figure 3. Meander width ratio (belt width/bankfull width) by stream type categories.



	A	B	C	D	DA	E	F	G
ENTRH.	<1.4	1.4–2.2	>2.2	N/A	>2.2	>2.2	<1.4	<1.4
SIN.	<1.2	>1.2	>1.4	<1.1	1.1-1.6	>1.5	>1.4	>1.2
W/D	<12	>12	>12	>40	<40	<12	>12	<12
SLOPE	.04–.099	.02–.039	<.02	<.02	<.005	<.02	<.02	.02–.039

Figure 4. Illustrative guide showing cross-sectional configuration, composition and delineative criteria of major stream types.



1 Values can vary by ± 0.2 units as a function of the continuum of physical variables within stream reaches.

2 Values can vary by ± 2.0 units as a function of the continuum of physical variables within stream reaches.

Figure 5. Key to classification of natural rivers.

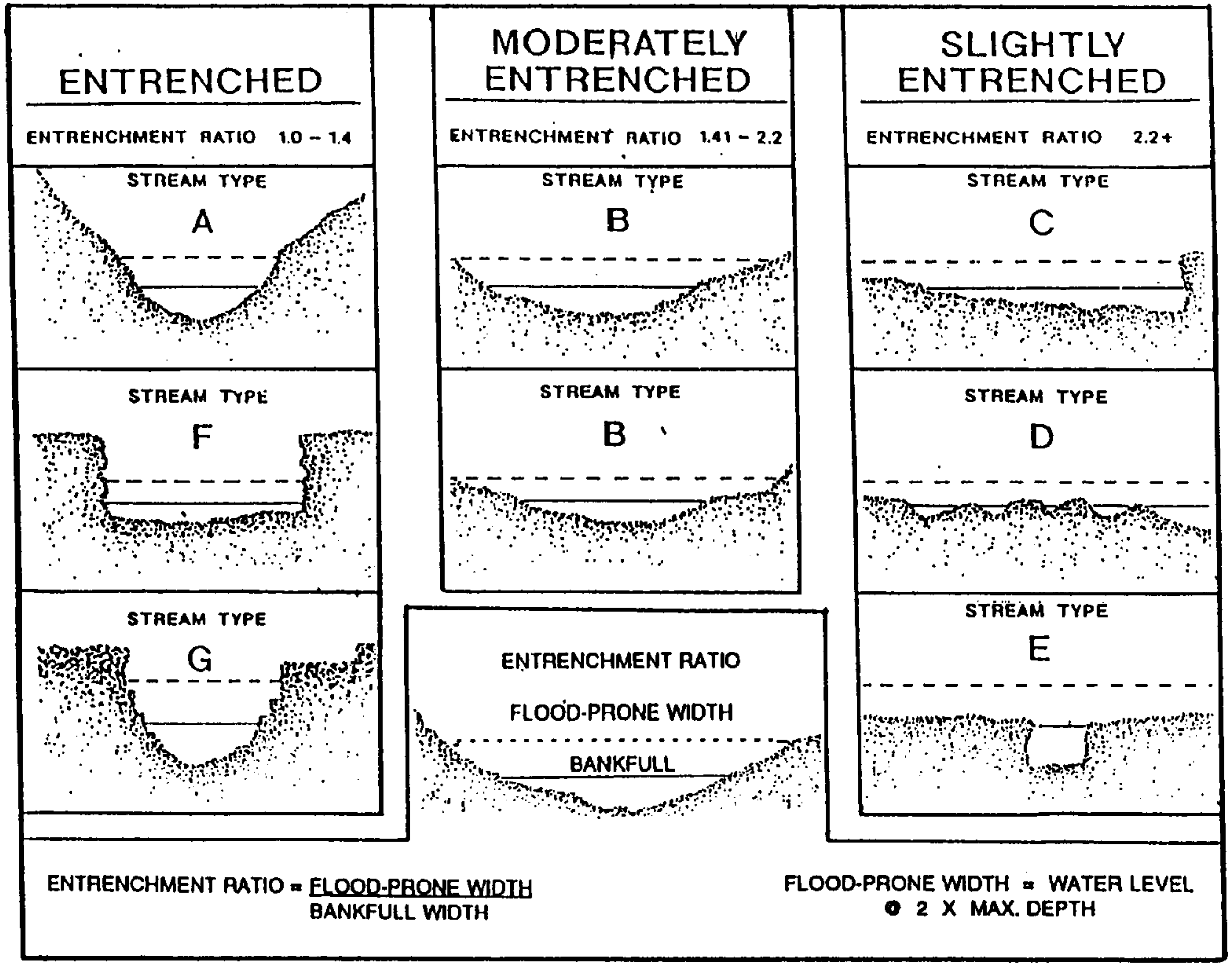


Figure 6. Examples and calculations of channel entrenchment.

Table 3. Management interpretations of various stream types.

Stream Type	Sensitivity to Disturbance[1]	Recovery Potential[2]	Sediment Supply[3]	Streambank Erosion Potential	Vegetation Controlling Influence[4]
A1	very low	excellent	very low	very low	negligible
A2	very low	excellent	very low	very low	negligible
A3	very high	very poor	very high	high	negligible
A4	extreme	very poor	very high	very high	negligible
A5	extreme	very poor	very high	very high	negligible
A6	high	poor	high	high	negligible
B1	very low	excellent	very low	very low	negligible
B2	very low	excellent	very low	very low	negligible
B3	low	excellent	low	low	moderate
B4	moderate	excellent	moderate	low	moderate
B5	moderate	excellent	moderate	moderate	moderate
B6	moderate	excellent	moderate	low	moderate
C1	low	very good	very low	low	moderate
C2	low	very good	low	low	moderate
C3	moderate	good	moderate	moderate	very high
C4	very high	good	high	very high	very high
C5	very high	fair	very high	very high	very high
C6	very high	good	high	high	very high
D3	very high	poor	very high	very high	moderate
D4	very high	poor	very high	very high	moderate
D5	very high	poor	very high	very high	moderate
D6	high	poor	high	high	moderate
DA4	moderate	good	very low	low	very high
DA5	moderate	good	low	low	very high
DA6	moderate	good	very low	very low	very high
E3	high	good	low	moderate	very high
E4	very high	good	moderate	high	very high
E5	very high	good	moderate	high	very high
E6	very high	good	low	moderate	very high
F1	low	fair	low	moderate	low
F2	low	fair	moderate	moderate	low
F3	moderate	poor	very high	very high	moderate
F4	extreme	poor	very high	very high	moderate
F5	very high	poor	very high	very high	moderate
F6	very high	fair	high	very high	moderate
G1	low	good	low	low	low
G2	moderate	fair	moderate	moderate	low
G3	very high	poor	very high	very high	high
G4	extreme	very poor	very high	very high	high
G5	extreme	very poor	very high	very high	high
G6	very high	poor	high	high	high

[1] Includes increases in streamflow magnitude and timing and/or sediment increases.
[2] Assumes natural recovery once cause of instability is corrected.
[3] Includes suspended and bedload from channel derived sources and/or from stream adjacent slopes.
[4] Vegetation that influences width/depth ratio-stability.

10. DEFINITIONS OF AQUATIC COMMUNITY HABITAT TYPES

A habitat type as used here is a unit of stream having a unique structure and function important to fish. There are two subdivisions of habitat types: Macro- and Micro- habitat types. Micro-habitats are distinct units of the stream whose length is less than one channel width and whose width is less than one-half channel width. All distinct units larger than this are considered macro-habitats.

The definitions were derived from: Western Division, American Fisheries Society (1985), Platts, Megahan, and Minshall, 1983, and Bisson and others (1981). These are sources frequently cited for habitat definition and characterization.

I. **POOL**

- An area of the stream that has reduced water velocity
- Water depth is deeper than surrounding areas
- The water surface gradient at low flow is often near zero
- The bed is often concave in shape and forms a depression in the thalweg profile
- Pools are formed by features of the stream that cause local deepening of the channel. This results from lateral constrictions in flow or by sharp drops in the water surface profile. They include:
    - Plunge pool created by water passing over or through a complete or nearly complete channel obstruction, scouring out a basin below. They are often associated with large debris and are usually macro-habitat
    - Dammed pools impounded upstream of a complete or nearly complete channel blockage caused by log jams, beavers, rockslides, boulders, etc. They are usually macro-habitat
    - A meander or corner pool is a lateral scour pool resulting from a sudden shift in channel direction and occurs along the outcurves of channel meanders. These are usually macro-habitat.
    - Backwaters caused by an eddy along the channel margin or by back-flooding upstream form an obstruction such as large woody debris, boulders, root wads, etc. - usually micro-habitat
    - Trenches or slot-like depressions formed usually in bedrock channels in long linear shapes - usually micro-habitat
    - Lateral scour around local obstructions such as wing deflectors, boulders, individual logs, etc - usually micro-habitat

II. **RIFFLE**

- Water flows faster than surrounding stream area
- Water is shallower than surrounding stream (< 20 cm or .6 ft in depth)
- Water surface is agitated relative to the surrounding stream
- Water surface gradient is steeper than the surrounding stream

There are three types of riffles:

- Low gradient: Water is shallow (< 20 cm or .6 ft deep), water velocity is moderate at 20-50 cm/sec, water surface gradient is less than 4% and water flows mostly on gravel or cobble substrate.

- Rapids: Water is swiftly flowing (> 50 cm/sec), turbulence is considerable, water surface gradient is greater than 4%, and substrate is mostly boulders or cobbles.
- Cascades: A series of steps or small waterfalls associated with bedrock or boulders. There is considerable water surface gradient, and small plunge pools may be associated with the type.

III. GLIDE

- Too shallow to be pool (< 30 cm deep, and too slow to be a run (< 20 cm/sec)

- Water surface gradient is nearly zero

- No pronounced turbulence on the water surface

- Substrate is typically gravel and cobble

As micro-habitat, glides usually occur at the downstream transition between pools and riffles. As macro-habitat, glides occur in long, low gradient stream reaches with stable banks and no large flow obstructions.

IV. RUN

- Too deep to be a riffle (> 30 cm deep), and too fast to be a pool (> 20 cm/sec)

- No pronounced water surface agitation

- The slope of the water surface is roughly parallel to the overall stream reach gradient

- Substrate is typically gravel and cobble

Glides are micro-habitats that usually occur at the downstream transition between pools and riffles and along the length of gradual channel constrictions where deepening is not associated with bed scour or bed depressions.

V. POCKET WATERS

- An area of stream forming a series of small pools surrounded by swiftly flowing water

- The small pools form behind boulders, rubble, or logs and create shallow habitats where fish feed and rest away from faster waters surrounding the pockets

- Distinguished from riffles by the prevalence of small pools associated with the type

11. SUGGESTED RIPARIAN PLANT IDENTIFICATION KEYS AND RIPARIAN COMMUNITY TYPE GUIDES

Brunsfeld, S.J. and F.D. Johnson. 1985. Field guide to the willows of east-central Idaho. Forest, Bulletin Number 39, Wildlife and Range Experiment Station, University of Idaho. Moscow, ID.

Cronquist, A., A.H. Holmgren, N.L. Holmgren, and J.L. Reveal. 1986. Intermountain flora, vascular plants of the intermountain west, U.S.A. Volumes 1 through 6. The New York Botanical Garden. Bronx, NY.

Hansen, P.L., S.W. Chadde, and R.D. Pfister. 1988. Riparian dominance types of Montana. Miscellaneous Publication No. 49. Montana Riparian Association. University of Montana. Missoula, MT.

Hansen, P., K. Boggs, R. Pfister, and J. Joy. 1991. Classification and management for riparian and wetland sites in Montana (draft version 1). Montana riparian Association. Montana Forest and Conservation Experiment Station. School of Forestry. University of Montana. Missoula, MT.

Herman, F.J. 1970. Manual of the carices of the Rocky Mountains and Colorado basin. Agricultural Handbook No. 374. USDA, Forest Service. Washington, DC.

Herman, F.J. 1975. Manual of the rushes (Juncus spp.) of the Rocky Mountains and Colorado basin. USDA, Forest Service. General Technical Report RN-18. Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO.

Hitchcock, A.S. 1971. Manual of the grasses of the United States, Volumes one and (second edition) two. Dover Publications, Inc. New York City, NY.

Hitchcock, L.C. and A. Cronquist. 1973. Flora of the pacific northwest. University of Washington Press. Seattle, WA.

Hitchcock, C.L., A Cronquist, M. Ownbey, and J.W. Thompson. 1977. Vascular plants of the pacific northwest, volumes I - V. University of Washington Press. Seattle, WA.

Kovalchik, B.L. 1987. Riparian zone associations, Deschutes, Ochoco, Fremont, and Winema National Forest. R6-ECOL-TP-279-87. USDA, Forest Service, Pacific Northwest Region. Portland, OR.

Kovalchik, B.L., W.E. Hopkins, and S.J. Brunsfeld. 1988. Major indicator shrubs and herbs in riparian zones on national forests of central Oregon. R6-ECOL-TP-005-88. USDA, Forest Service. Pacific Northwest Region. Portland, OR.

Manning, M.E. and W.G. Padgett. 1992. Riparian Community Type Classification for the Humbold and Toiyabe National Forests, Nevada and Eastern California (Draft). USDA, Forest Service, Intermountain Station. Ecology and and Classification Program. Ogden, UT.

Padgett, W.G., A.P. Youngblood, and A.H. Winward. 1989. Riparian community type classification of Utah and southeastern Idaho. USDA, Forest Service. Intermountain Region. Ogden, UT.

Youngblood, A.P., W.G. Padgett, and A.H. Winward. 1985. Riparian community type classification of eastern Idaho--western Wyoming. R4-ECOL-85-01. USDA, Forest Service. Intermountain Region. Ogden, UT.

APPENDIX C

RECONNAISSANCE

1. Field Data Sheet - Reconnaissance - Riparian Classification
2. Instruction for Preparing Reconnaissance - Riparian Classification
3. Field Data Sheet - Reconnaissance - Habitat
4. Instructions for Reconnaissance - Habitat

1. RECONNAISSANCE - RIPARIAN CLASSIFICATION

Stream Name: ____________ Sub-Area: ____________ Date: ____________

Agency: ____________ EPA No.: ____________

Map Name: ____________ Examiner(s): ____________

Stream and Valley Bottom Classification:

Valley Bottom Type: ____________ Gradient: ____________ Aspect: ____________

Elevation: Upper ____________ Lower ____________ Middle ____________

Complex Size: Length ____________ Width ____________ Area ____________

Confinement: ____________ Sinuosity: ____________ Stream Type: ____________

SOILS

Dominant Soil Family(ies)	% Sub-area	Compaction
____________	____________	Sl / Md / Sv
____________	____________	Sl / Md / Sv
____________	____________	Sl / Md / Sv

VEGETATION DESCRIPTION: DOMINANCE BY COMMUNITY TYPES

Community Type	% Sub-area	Potential Community Type
____________	____________	____________
____________	____________	____________
____________	____________	____________
____________	____________	____________
____________	____________	____________
____________	____________	____________

ADJACENT (non-riparian) VEGETATION (looking down stream)

Left ____________ Right ____________

GREEN LINE (Hydric Vegetation) ____________% **PHOTO ID:** ____________

BEAVER No. Active Dams ____________ No. Inactive Dams ____________ Other ____________

LAND USE ACTIVITIES AND ESTIMATED INFLUENCE ON RIPARIAN AREA

Livestock	Irrig. Cropland	Dry Cropland	Mining	Timber	Roads	Recreation	ORV	Other
______	______	______	______	______	______	______	______	______

Stream/Riparian Classification: ____________

2. INSTRUCTIONS FOR PREPARING RECONNAISSANCE - RIPARIAN CLASSIFICATION

Stream Name: Provide the name of the stream segment being classified.

Sub-area: Provide the name and/or number for the complex. An individual form should be completed for each sub-area described on the Basic Information Data Sheet and other sub-areas defined during the reconnaissance inventory.

Date: Date data is collected.

Agency: List the agency responsible for the classification.

EPA No.: List the EPA Stream Reach Number.

Examiner(s): List the names of the individuals obtaining the data.

Map Name: Provide the name(s) of the USGS topographic map or other map being used.

Valley Bottom Type: Valley bottom type for the sub-area. (See page B-1)

Gradient: Stream gradient for the specific sub-area.

Aspect: General aspect of the sub-area.

Elevation: Provide the upper, middle (if needed), and lower elevation of the sub-area.

Complex Size: The size of the sub-area (riparian zone); length in miles, width in miles, and the area in acres.

Confinement: How restrictive the valley walls or river terraces are to lateral movement (meander) by a stream channel. Use the following descriptions:

> **Confined** - Stream channel lateral movement is controlled by valley walls or terraces.
>
> **Moderately Confined** - Stream channel lateral movement is occasionally deflected by valley walls or terraces.
>
> **Unconfined** - Stream channel is not controlled by valley walls or terraces.

Sinuosity: The ratio of the channel length divided by the valley bottom length.

Stream Type: Rosgen stream type and stream size (see Appendix B).

Dominant Soil Family: List the dominant soil family(ies) in the Sub-area.

Percent of Area: Estimate the percentage (to the nearest 5 percent) of the area for each dominant soil family on the riparian area.

Compaction: Estimate the soil compaction resulting from land use activities for each soil family.

Community Type: List the dominant riparian communities on the stream associated riparian area. Use the Riparian Vegetation Inventory form to determine Riparian Community Type (see Appendix B).

% Sub-area: The percentage (to the nearest 5 percent) sub-area for each community type.

Potential Community Type: The name of the potential natural community.

Adjacent Vegetation: List the adjacent upland plant community for each bank, left and right (looking down stream).

Green Line: Estimate the percentage of the total green line (both banks) contain desirable hydric vegetation.

Beaver: Record the number of active beaver dams, inactive beaver dams, and other information concerning beaver activity in the Sub-area.

Land Use Activities: Circle the land use activities influencing the stream and riparian area. Estimate the relative influence; high, medium, or low.

Stream/Riparian Classification: The classification consists of the sub-area number, dominant soil family, stream type (Rosgen), and dominant vegetation community.

3. RECONNAISSANCE - HABITAT

Stream Name: ______________________ Sub-area: ________________ Date: ______

Stream Reach No.: ____

Agency: ________________ Observer(s): ________________ Page ____ of ____

HABITAT UNIT									
Length									
Bankfull Width									
Bankfull Depth									
Low Flow Width									
Low Flow Depth									
Maximum Low Flow Depth									
Flood Zone Width									
Tailout Depth (Pool only)									
Substrate (%)									
Sand/Silt (> 0.1")									
Gravel (0.1 to 2.5")									
Cobble (2.5 to 10")									
Boulder (< 10")									
Bedrock									
Cobble Embeddedness (%)									
Stream Banks									
Covered/Stable									
Uncovered/Stable									
Covered/Unstable									
Uncovered/Unstable									
Bank Slope > 135°									
Habitat									
Undercut Bank									
Overhanging Vegetation									
Canopy Density									
Pool Complexity (Pools only)									
Large Woody Debris (LWD)									

Total of Length of Habitat Units: Pools ______ Riffles ______ Runs ______ Glides ______

4. INSTRUCTIONS FOR RECONNAISSANCE - HABITAT

Stream Name: List the steam segment name inventoried.

Sub-Area: Provide the number or name of the sub-area described in the inventory.

Date: Date of the inventory.

EPA Stream Reach No.: List the EPA stream reach number.

Agency: Provide the name of the agency responsible for the inventory.

Observer: Provide the names of the individuals completing the inventory.

Page __ of __: The current page out of all of pages of data for the sub-area.

INSTRUCTIONS COMMON TO ALL ELEMENTS

Reconnaissance inventory may be completed at various intensities from a single ocular estimate to sampling at least five stream segments in each sub-area. Inventory a sufficient number of habitat types to characterize the stream segment.

Habitat Unit: List the habitat type evaluated: Pool (PL), riffle (RF), run (RN), or glide (GD). Number each habitat type consecutively for each sub-area, i.e. PL1, PL2, RF1, RF2, RF3.

Length: Measured along the thalweg.

Bankfull Width: Measured at a specific point that is representative of the average width of the habitat unit.

Bankfull Depth: The maximum water depth at the bankfull level at the same location as the bankfull width.

Low Flow Width: The average width of the existing water level (stable low flow) for the habitat unit.

Low Flow Depth: Measure riffles, runs, and glides at the average width transect at 1/4, 1/2, and 3/4 the width of the existing water level. Measure pools along a cross-section at a midpoint between the pool tailout and the maximum depth. Add the three depths and divide by four (to compensate for the "0" depth measurement).

Flood Zone Width: The waters width at two times the bankfull depth.

Maximum Low Flow Depth: The maximum depth of the habitat unit.

Tailout Depth: The maximum depth of the pool tailout. This will give an indication of the residual pool depth.

Substrate Size: Estimate substrate composition using a Wolman Pebble Count or visual estimate.

Cobble Embeddedness: A visual estimate of cobble embeddedness of the substrate of the habitat unit. Only estimate the tailout for pool habitats. Cobble embeddedness is the percentage of cobbles embedded in sand or silt.

Bank Conditions: The percent of the length of the streambank (both banks) for the following classes:.

> ***Covered and Stable (Non-erosional).*** OVER 50 percent of the streambank surfaces are covered by vegetation in vigorous condition, or the banks are OVER 50 percent covered by materials (large cobble, boulders, or anchored rock) that prevent bank erosion. Streambanks are stable; that is, they DO NOT SHOW indications of alteration such as breakdown, erosion, tension cracking, shearing, or slumping.
> ***Covered and Unstable (Vulnerable).*** OVER 50 percent of the streambank surfaces are covered by vegetation in vigorous condition, or the banks are OVER 50 percent covered by materials that prevent bank erosion. Streambanks are unstable; that is, they DO SHOW indications of alteration such as breakdown, erosion, tension cracking, shearing, or slumping. Banks showing present erosion must be vertical or near-vertical in form.
>
> ***Uncovered and Stable (Vulnerable).*** LESS THAN 50 percent of the streambank surfaces are covered by

vegetation in vigorous condition, or the banks are LESS THAN 50 percent covered by materials that do not allow bank erosion. Streambanks are stable; that is, they DO NOT SHOW indications of alteration such as breakdown, erosion, tension cracking, shearing, or slumping. Such banks are bare, but they are not slumping or at a vertical or near-vertical bank angle.

Uncovered and Unstable (Eroding). LESS THAN 50 percent of the streambank surfaces are covered by vegetation in vigorous condition, or the banks are LESS THAN 50 percent covered by materials that do not allow bank erosion. Streambanks are unstable; that is, they DO SHOW indications of alteration such as breakdown, erosion, tension cracking, shearing, or slumping.

Bank Slope: The percentage of the length of both banks having a slope of 135° or greater is considered gently sloping banks. The water surface is 180°. The slope of the bank above the bankfull depth.

Undercut Bank: An estimate of the length of bank that is under cut. The undercut must be at least 12 inches and within 6 inches of the waters surface. Determine the length for both banks.

Overhanging Vegetation: The percentage of the length of both streambanks having overhanging live vegetation within 12 inches of the water surface and at least 12 inch over the water.

Canopy Density: Estimate the canopy cover using a spherical densiometer or ocular estimate.

Pool Complexity Index: Pool complexity index is a total of the codes (ranges from 0 to 10) for the following factors:

Depth: The depth deepest part of the pool less the depth of the tailout (residual pool depth).

Substrate: The dominant substrate in the pool.

Overhead Cover: The percent of the pool surface covered by overhead vegetation of turbulence.

Submerged Cover: The percent of the pool covered with large organic debris, small woody debris, or other cover at or below the water surface.

Bank Cover: The percentage of the streambank (both banks) covered with stumps, roots, or other debris on the bank providing cover.

Depth	Value	Substrate	Value	Overhead Cover	Value	Submerged Cover	Value	Bank Cover	Value
< 0.5′	0	< 2.5"	0	< 10%	0	< 10%	0	< 25%	0
0.5 - 1.5′	1	2.5 - 10"	1	10 - 25%	1	10 - 25%	1	25 - 50%	1
> 1.5′	2	> 10"	2	>25%	2	> 25%	2	> 50%	2

Large Woody Debris (LWD): Woody debris with a length of 9 feet or 2/3 the bankfull width and at least 4 inches in diameter and within the bankfull channel unit. Record as follows:

No LWD present	0	LWD present, but infrequent	1
LWD present with some channel influence	2	LWD extensive with a major influence in channel characteristics	3

Total Length of Habitat Units: Measure or estimate total length (percentage or measured) for each of the habitat units within the sub-area, i.e. pool 50%, riffles 20%, runs 30%.

APPENDIX D

RIPARIAN VEGETATION INVENTORY

1. Riparian Vegetation Inventory
2. Instructions for Riparian Vegetation Inventory

RIPARIAN VEGETATION INVENTORY

Stream Name: ______________________ Sub-area: ____________ Date: ____________

EPA No.: ______________________ Observer: ______________________

Plant Name	Canopy Density (%)	Plant Name	Canopy Density (%)
GRASS & GRASSLIKE		**SHRUBS**	
Total Grass & Grasslike		Total Shrubs	
FORBS		**TREES**	
Total Forbs		Total Trees	

Riparian Community Type: ______________________

Potential Natual Community: ______________________

Classification Key Used: ______________________

INSTRUCTIONS FOR RIPARIAN VEGETATION INVENTORY

The Riparian Vegetation Inventory form provides a list of some of the important riparian plant species found in Idaho. It provides a convenient method for recording information.

1. Determine the important riparian vegetation communities within the sub-area from maps, aerial photos, or soil survey information.

2. Mark or list all plant species present within the community.

3. Estimate or measure the percent canopy cover for each plant species.

4. Determine the appropriate riparian community type, riparian association, or habitat type from the references listed below for each important plant community.

5. List the key or source used to determine the appropriate riparian community description. If the type is not found, describe the riparian community.

6. Describe the potential natural community (PNC) for the classified community. Most of the descriptions are listed in the description of the community types in the publications listed below.

Riparian Community Type Keys:

Padgett, W.G., A.P. Youngblood, and A.H. Winward. 1989. *Riparian Community Type Classification of Utah and Southeastern Idaho.* USDA, Forest Service, Intermountain Region, R4-Ecol-89-01. Ogden, UT.

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